SECOND BOOK OF BOTANY.

A PRACTICAL GUIDE

TO THE

OBSERVATION AND STUDY OF PLANTS.

BY

ELIZA A. YOUMANS,

AUTHOR OF "THE FIRST BOOK OF BOTANY," EDITOR OF HENSLOW'S BOTANICAL CHARTS.

NEW YORK:
D. APPLETON & COMPANY,
549 & 551 BROADWAY.
1873.

INTRODUCTION.

THE First Book of Botany, for the use of beginners, was designed to cultivate the observing powers of the young by making plants themselves the regular objects of study. It was published three years ago, and adopted by numerous schools, and, upon trial, it proved so satisfactory that there have been frequent and urgent calls for a more advanced book upon the same method. After much delay, which I regret, but have been unable to avoid, a Second Book, carrying out the plan, is now ready, together with an instructive series of Botanical Charts, which will be helpful to both teachers and pupils.

In the preface to the First Book, and in an Essay reprinted at the end of the present volume, I have stated the purpose that led to these publications: the present extension of the method affords a suitable occasion for presenting some further considerations in illustration of it. I had two objects in view, one relating to the subject of Botany, and the other to the mental cultivation of the young.

As regards the science itself, it seemed to me to be very badly dealt with in the schools. In many it is not taught at all, and in others it is regarded as a kind of superfluous side-study, of such secondary importance that it matters little in what way it is treated. And so it is subordinated to the school routine, and pursued in a hurried and desultory manner, by books and recitations, and by memorizing second-hand information. It is perfectly well known that, in institutions of all grades, students often "go through" the botanical text-books

without giving any attention whatever to the objects they describe; or, if they do so at all, it is generally in an incidental and irrational way—perhaps by attacking the most complex part of the plant first, and picking flowers to pieces, so that the pupil may quickly indulge in the shallow pedantry of giving them their technical names. All this is unjust to the science. Like arithmetic, Botany is only to be acquired by first mastering its rudiments. And as, in arithmetic, the student is compelled to exercise his mind directly upon numbers, and work out the problems for himself, so in Botany, if worth pursuing at all, it should be studied in its actual objects. The characters of plants must become familiarly known by the detailed and repeated examination and accurate description of large numbers of specimens. The pupil must proceed step by step in this preliminary work, digesting his observations, and making the facts his own, until he becomes intelligent in regard to all the common varieties of plant forms and structures. It is because the text-books of Botany hitherto in use fail to provide for and to enforce this thoroughness of introductory study of the characters of plants—fail in the very groundwork of the subject—that the present plan of study has been prepared.

But, it will be asked, "Is botanical science, after all, worth acquiring in so painstaking a way?" This is an important question, and brings me to the higher purpose I had in the arrangement of these books. The uses of Botany are by no means to be measured by the interest or utility of the knowledge of plants. A thorough acquaintance with the science will be serviceable on its own account through life; but its merit is that it leads to an end beyond itself: it has great value as a means of mental cultivation. That branch of Natural History which treats of the vegetable kingdom ought to be, and can be, made corrective of a fundamental defect in our educational system. This deficiency is a lack of any provision for thoroughly exercising the minds of the young upon natural objects. Our plan of general education includes not a single subject that can secure the mental advantages arising from the direct and systematic study of Nature. We do a great deal in the way of "mental discipline," but the order and truth of things around us are not allowed to contribute to it. We train the faculty of calculation and drill the memory in lesson-

learning, but the realities of Nature find no place at our schools as means of mental unfolding—for training in observation, and for working the higher faculties of reason and judgment upon natural things. In short, for calling out the more important powers of the mind, by *actual exercise* upon the objects of surrounding experience, our educational system makes no provision whatever. Neither reading, writing, arithmetic, grammar, nor geography, brings the mind into contact with Nature at all; and even the sciences of physics, chemistry, physiology, and botany, are usually acquired from books, and with so little regard to the real objects of which they treat, that as means of mental improvement they are of very slight service.

That modern education, in all its gradations, is profoundly deficient in this respect, has long been recognized and deplored by the most enlightened educators. Dr. Whewell, for example, late Master of Trinity College, Cambridge, in one of his able works upon Education, says: "The period appears now to be arrived when we may venture, or rather, when we are bound to endeavor, to include a new class of fundamental ideas in the elementary discipline of the human intellect. This is indispensable if we wish to educe the powers which we know it possesses." Again, he remarks: "There are perverse intellectual habits very commonly prevalent in the cultivated classes, which ought, ere now, to have been corrected by the general teaching of Natural History. We may detect, among speculative men, many prejudices respecting the nature and rules of reasoning which arise from pure mathematics having been so long and so universally the instrument of intellectual cultivation." And again: "In order that Natural History may produce such an effect, it must be studied by the inspection of the *objects* themselves, and not by the reading of books only. Its lesson is that we must, in all cases of doubt or obscurity, refer, not to words or definitions, but to things. The Book of Nature is its dictionary; it is there that the natural historian looks to find the meaning of the words which he uses."[1]

To gain the mental benefits of the study of Natural History here proposed, the pupil's attention requires to be concentrated upon a limited portion of it, which is to be thoroughly

[1] "*Novum Organum Renovatum*," p. 170.

mastered, and Botany presents special and eminent advantages for this purpose. He is brought face to face with Nature, and his first and constant work is the observation of phenomena; not merely looking with the eye, but recognizing with the mind. The science consists of a comprehensive system of organized and closely-dependent truths, which it is the business of the student to trace out and rediscover for himself. From the beginning he is engaged in comparing his observations, and reasoning upon his facts. As nothing can be done without terms, to mark his discriminations, he commences their use at the outset; and, as the language of Botany is more precise than that of any other science, there is constant drill in accuracy of description. As he extends his familiarity with plant characters, the work of comparison and grouping calls for a higher exercise of thought. Finally, in classification, which is the goal of all his preparatory study, he engages with problems of increasing complexity —the grouping of plants by masses of resemblances—distinction of kinds and classes of things by likenesses and differences of unequal values, and the formation of groups in subordination to each other—all of which involve the highest exercise of judgment.

Thus, the thorough study of Botany as a branch of Natural History, and as a *means* of education, not only "communicates precision, clearness, and method to the intellect, through a great range of its operations," but its discipline is corrective of the most common defects of education, and is eminently applicable in forming judgments upon the ordinary affairs of life. Carelessness in observation, looseness in the application of words, hasty inferences from partial data, and lack of method in the contents of the mind, are common faults even among the cultivated, and it is precisely these faults that the study of botanical science, by the method here proposed, is calculated to remedy. That the habit of systematic arrangement, in which the study of botanical classification affords so admirable a training, is equally valuable in methodizing all the results of thought, is testified to by one of the most intellectual and influential men of our time, Mr. John Stuart Mill. He was a regular field botanist, and cultivated the subject with a view to its important mental advantages; and his

great work on logic took a form which could not have been given it if the author had not been a working naturalist as well as a logician. In the second volume of his "System of Logic" Mr. Mill says:

"Although the scientific arrangements of organic Nature afford as yet the only complete example of the true principles of rational classification, whether as to the formation of groups or of series, these principles are applicable to all cases in which mankind are called upon to bring the various parts of any extensive subject into mental coördination. They are as much to the point when objects are to be classed for purposes of art or business, as for those of science. The proper arrangement, for example, of a code of laws, depends on the same scientific conditions as the classifications in natural history; nor could there be a better preparatory discipline for that important function than the study of the principles of a natural arrangement, not only in the abstract, but in their actual application to the class of phenomena for which they were first elaborated, and which are still the best school for learning their use."

If, therefore, the object of education is the completest cultivation of the powers of the mind, botanical science evidently has a very strong claim to a regular and leading place in our scheme of school-studies. But it will be a grave mistake to suppose that its benefits can be secured by the mere use of text-books, however full and valuable the information they contain. Nor are they to be gained by the casual examination of plants, nor by the analyses of a few flowers, with the aid of keys and dictionaries, nor in the limited time usually allotted to the subject. The study must be commenced early and pursued steadily by the method of direct observation, until its elementary facts and principles are made entirely familiar.

It is the claim of the First and Second Books of Botany that they lead the pupil over this indispensable ground, and, if faithfully followed, they will lay the solid foundation of the science, and will contribute to that desirable bent and habit of the intellect which natural-history studies are best calculated to impart. They are not intended to supersede the regular treatises upon the science, but to supplement them and prepare for them. They are guides to self-education, and are adapted for use in school or out, by teachers and mothers, whether

they know any thing of the subject or not, and by pupils without any assistance at all. A large amount of time will not be required, but the exercises should be so frequent and regular as to keep the subject prominently in mind, and maintain the interest in vegetable forms.

The Second Book begins where the First left off. The use of magnifying-glasses and microscopes is commenced, and the work now becomes more close and thorough. As soon as the more important features of the flower are known, the pupil is introduced to the leading principles by which plants are arranged, and set to making groups of those that most nearly resemble each other in important characters. He is here called upon to do his own thinking, and to form opinions as to the amount of resemblance between different plants. He has to decide whether a certain group of characters presented by his specimen is most like one or another group presented by other plants, and this leads on to the comparison and estimate of the relations of different groups with each other. It is thus that the discipline of the judgment and reason begins to be secured at an early stage of the study, and is continued with more and more completeness as it goes on.

I am much indebted to the kindness of Mr. George C. Woolson for having carefully revised the proofs of the present volume, and have also to thank Prof. George Thurber for valuable suggestions, both in regard to the present work and the revised edition of Prof. Henslow's Charts.

E. A. Y.

NEW YORK, *June*, 1873.

HENSLOW'S BOTANICAL CHARTS.

Large colored diagrams for teaching botany are so valuable that, in the absence of any publications for the full and systematic illustration of the subject, lecturers have been in the habit of roughly preparing them for class-room use. Recognizing this want of schools and students, Prof. J. S. Henslow, the eminent English botanist, who has done so much to simplify and improve the elementary teaching of the subject, took the matter up; and one of the last works of his life was to prepare a set of botanical charts for educational purposes. There was perhaps no other living man so competent to the task, as his thorough knowledge of the science, his experience as a lecturer to the Cambridge students when he was professor in that university, and his subsequent teaching of the parish children at Hitcham, qualified him to meet the wants of all grades of learners. He prepared a series of nine large sheets, and, as their publication was expensive, it was undertaken as an important educational work by the Science and Art Department of the English Educational Council. "Henslow's Botanical Diagrams" have had a high reputation for their scientific accuracy, their completeness of illustration, their judicious selection of typical specimens, and their skilful arrangement for the purposes of education. In bringing out a method of elementary botany, which desires to give every advantage in its thorough acquisition, the author of the First and Second Books felt the need of large colored diagrams, and, as there is nothing of the kind in this country, while the importation of Henslow's series is costly, her publishers were induced to incur the very considerable expense of publishing a revised edition of the English charts. This revision and reissue were the more necessary, as the foreign edition has one very serious defect; it was compressed into so small a space that the figures often overlapped, producing an indistinct and confused effect.

The American edition consists of six large charts, and the pictures are spread over twice the original area, giving much greater distinctness and a very attractive aspect to the series. Several American specimens have been substituted for English species which do not occur in this country, and illustrations of the classes of flowerless plants have been added, for which Prof. Henslow did not seem to find room.

In the plan of the charts, the plant is first represented of its natural size and colors; then a magnified section of one of its flowers is given, showing the relations of the parts to each other. Separate magnified views of the different floral organs, exhibiting all the botanical characters that belong to the group of which it is a type, are also represented. The charts contain nearly five hundred figures colored to the life, and which represent twenty-four orders and more than forty species of plants, showing a great variety of forms and structures of leaf, stem, root, inflorescence, flower, fruit, and seed, with numerous incidental characters peculiar to limited groups. All these are so presented as to be readily compared and contrasted with each other.

The charts are not designed to supersede the study of plants, but only to facilitate it. Their office is the same as the illustrations of the book; but they are more perfect, and bring the pupil a step nearer to the objects themselves. Many plant characters are so minute that they are difficult to find, and much is gained by referring first to the enlarged and colored representations.

Besides this special assistance in object-study, the charts will be of chief value in bringing into a narrow compass a complete view of the structures and relations of the leading types of the vegetable kingdom. In fact, they are designed to present, fully and clearly, those groupings of characters upon which orders depend in classification; while in several cases of large and diversified orders the characters of leading genera are also given by typical specimens. The charts will thus be found equally valuable to the beginner, the intermediate pupil, and the advanced student. A Key accompanies the charts, and they can be used with any botanical text-books, and during the season of plants they should be upon the walls of every school-room where botany is studied.

TO TEACHERS.

THE First Book of Botany was prepared for young children, and was made very simple and elementary, to meet the wants of juvenile minds; but it provides for a course of rudimentary observations which are not to be dispensed with by beginners of any age. As, however, pupils twelve or fifteen years old will hardly be content to go slowly over exercises adapted to young children, it may be asked how these should proceed with the First Book. In reply, it may be said, that Chapter IV. of the First Book, upon the flower, and which contains the first part of the flower-schedule, is the only portion of it that is *indispensable* to entering upon the Second Book. After this is acquired, there need be no difficulty in using both books at the same time.

I would suggest that an excellent way for older pupils to familiarize themselves with the plant characters pointed out in the First Book, is at once to set about the preservation of plants, as described in Chapter XXI. of the Second Book.

They may begin by putting a variety of leaves in press, having first carefully compared them with the pictures and definitions of Chapter I., First Book. At each change of the driers, the features of these leaves will be observed, and the names denoting them recalled, and by the time they are dried for mounting, it will be possible, by the aid of the last schedule of the chapter, to write, upon the paper holding the specimen, an accurate scientific description of it. Let this be followed by the pressing of entire plants, after comparing their different organs with the examples shown in the chapters on the Stem, Inflorescence, and Roots. The attention thus drawn to their characters will be kept alive in changing them

and caring for them, and the attempt completely to describe them, when dried and mounted, will go far toward fixing in the mind ideas of the forms and structures of the various organs, and the terms needed in description.

But the constant temptation of such pupils will be toward haste and inadequate observation. The danger is that plants enough will not be collected, and that the parts of such as are collected will not be studied with sufficient care. The influence of the teacher will therefore be constantly needed to check the too rapid passage of older pupils over that portion of Botany included in the primary book.

CONTENTS.

COURSE FIRST.

COURSE SECOND.

THE SECOND BOOK OF BOTANY.

COURSE FIRST.

DESCRIPTIVE BOTANY.

CHAPTER I.

THE FLOWER.

WITH the present book, we are to continue the method of studying plants that was commenced with "The First Book of Botany." It is assumed that the pupil has begun the work of practical observation, and made himself familiar with the general features of plants, as far as the "First Book" goes. As before, the indispensable condition of the method is, to collect a large variety of specimens to be studied. The first duty of each pupil is, to assist in gathering these plant-specimens, and this should be in every way encouraged, and positively required, by the teacher.

EXERCISE I.

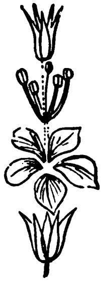
The Symmetry of Flowers.

Having gathered a variety of flowers, look carefully at the pictures and definitions given in the fol-

lowing exercise. When you have found their meaning, you will be prepared to study your flowers.

A Symmetrical Flower is one having the same number of parts in each of its whorls, or, if not the same, then multiples of the prevailing number.

Fig. 1.



Quinary Symmetry.

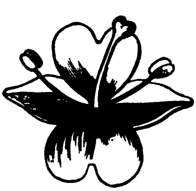
Fig. 2.

Quinary Symmetry (Gray).

Figs. 1 and 2 represent a symmetrical flower. It consists of five sepals, five petals, five stamens, and five carpels. It would still be symmetrical if the number of sepals, or of petals, or stamens, or carpels, were ten, twenty, or any multiple of five.

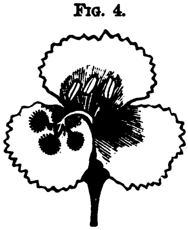
A flower with its parts arranged in twos, or multiples of two, has *dimerous*, or *binary symmetry* (Fig. 3).

Fig. 3.



Binary Symmetry.

Fig. 4.



Ternary Symmetry.

When the parts of the floral whorls are in threes, the symmetry is *trimerous*, or *ternary* (Fig. 4).

When the parts are in fours, the symmetry is *tetramerous*, or *quaternary*.

When the parts are in fives, the symmetry is said to be *pentamerous*, or *quinary* (Figs. 1 and 2).

If you have the botanical charts, look at the magnified flowers represented on them, and point out the symmetrical ones, naming the kind of symmetry they exhibit. Then examine your living specimens. These will, of course, vary with the season. We will suppose, for example, that you have the pea, morning-glory, violet, portulacca, buttercup, Saint-John's-wort, hollyhock, potato-blossom, evening primrose, lily, etc. Decide which are symmetrical and which are unsymmetrical, placing the two kinds apart. Re-examine the symmetrical ones, and tell which have binary symmetry, which ternary, which quaternary, and which quinary.

Binary—From the Latin *binarius*, compounded of two, parts in twos.

Ternary—Latin *ternarius*, consisting of threes.

Quaternary—Latin *quaternarius*, containing four, by fours.

Quinary—Latin *quinus*, five, arranged in fives.

Dimerous—From two Greek words, meaning *twofold* and *part*.

Trimerous—From two Greek words, meaning *three*, or *thrice*, and *part*.

Tetramerous—From two Greek words, signifying *four* and *part*.

Pentamerous—From two Greek words, meaning *five* and *part*.

EXERCISE II.

Complete and Incomplete Flowers.

The collection of flowers that in the previous exercise were separated into symmetrical and unsymmetrical ones, may now be rearranged, separating the complete from the incomplete, according to the following definitions:

COMPLETE FLOWERS consist of calyx, corolla, stamens, and pistil (Fig. 5).

FIG. 5.

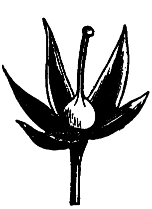
Complete Flower.

INCOMPLETE FLOWERS have one or more of the floral whorls absent (Figs. 6 and 7).

FIG. 6.

Incomplete Flower.

FIG. 7.



Incomplete Flower.

Find upon the charts examples of complete and incomplete flowers.

If any of the flowers present strange appearances, let them pass; by-and-by, after further study, you can put them where they belong.

EXERCISE III.

Essential Organs and Protecting Organs.

The chief purpose of the flower is the production of seed; but, to this end, some of its parts are more necessary than others: for example, the action of both stamens and pistil is needed in the formation of seeds, while they are often produced without the presence of either calyx or corolla. The stamens and pistil are therefore called the *essential organs* of flowers; and, as the calyx and corolla cover and nourish these, they have been called the *protecting organs.*

Point out upon the charts the protecting organs of flowers. Point out the essential organs. Do you find both sets in all the flowers represented?

Examine your collection of flowers, and point out in each specimen the essential organs and the protecting organs.

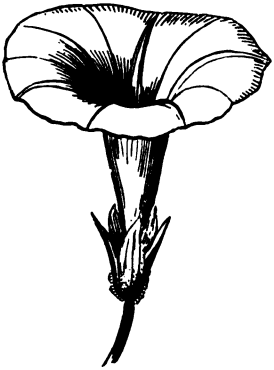
NOTE.—The same kinds of flowers will be used over and over in observing their different features in successive exercises. But, as pupils proceed, new kinds should be constantly sought for, and, when obtained, they must be examined, with reference to all the points of the preceding exercises. New kinds of flowers are constantly opening as the season advances; these, as they appear, should be observed with reference to all the points that have been before studied.

EXERCISE IV.

Dichlamyd'eous, Monochlamyd'eous, and Achlamyd'eous Flowers.

When the protecting organs, calyx and corolla, are present in a flower, it is said to be *dichlamydeous* (Fig. 8).

FIG. 8.



Dichlamydeous Flower (Gray).

When there is but one whorl of protecting organs, whatever its color or texture, it is called a *calyx*, and the flower is *monochlamydeous* (Figs. 9 and 10).

FIG. 9.

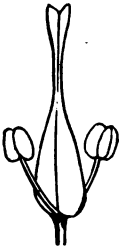
Monochlamydeous Flower.

FIG. 10.

Monochlamydeous Flower.

A flower destitute of protecting organs is *achlamydeous* (Fig. 11).

FIG. 11.



Achlamydeous Flower.

Achlamydeous flowers are said to be *naked.*

After observing the pictures, and reading the definitions of this exercise, you may find upon the charts all the pictures of dichlamydeous flowers; of monochlamydeous flowers; of achlamydeous, or naked, flowers. Then look over your living specimens again, putting the dichlamydeous ones by themselves; the monochlamydeous; the achlamydeous. Pay no attention to the doubtful instances; there will be fewer and fewer of these as your observations proceed.

Dichlamydeous—From two Greek words, signifying *twice* and *mantle*, having two coverings, calyx and corolla. Both calyx and corolla.

Monochlamydeous—From two Greek words, signifying *single* and *cloak*, having a single covering; that is, a calyx without a corolla, or a corolla without a calyx. With a single floral envelope.

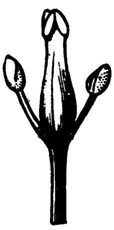
Achlamydeous—From two Greek words, signifying *without* and *garment.* Naked, having no floral envelope.

EXERCISE V.

Perfect, Imperfect, and Neutral Flowers.

Pictures, illustrating this and the following exercise, may be found upon the charts. Living specimens of the kinds described will, perhaps, but rarely occur in the collections made for study. It would be well, therefore, to keep a constant lookout for them. You are likely to get them in this way before a long time, and a special search might not be successful.

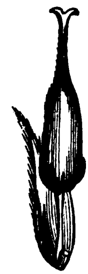
Fig. 12.



A Perfect Flower.

Fig. 13.

Fig. 14.



Imperfect Flowers.

A Perfect Flower has both the essential organs (Fig. 12).

An Imperfect, or Diclinous, flower has but one of the essential organs. If it have stamens only, it is said to be *staminate* (Fig. 13); if pistil only, it is said to be *pistillate* (Fig. 14).

Neutral Flowers are destitute of both stamens and pistil (Fig. 15).

When imperfect flowers are staminate (Fig. 13), they are said to be *sterile*, because they never produce seed. Sometimes they are spoken of as *male* flowers.

FIG. 15.

A Neutral Flower.

When imperfect flowers are pistillate (Fig. 14), they are said to be *fertile*, because they bear seed. They are also called *female* flowers.

Perfect flowers, like Fig. 12, are said to be *hermaphrodite*, because both sexes are united in the same individual.

It will be well firmly to associate the following characters with the kinds of flowers they represent:

A perfect flower is indicated thus, ☿.

A staminate, sterile, or male flower, thus, ♂.

A pistillate, fertile, or female flower, thus, ♀.

Look over the charts for examples of perfect, imperfect, and neutral flowers.

Diclinous—From two Greek words, signifying *twofold* and *bed*, having the stamens and pistils in separate flowers.

EXERCISE VI.

Monœcious, Diœcious, and Polygamous Plants.

When both staminate and pistillate flowers grow upon the same plant (Fig. 16), it is said to be *monœcious.*

Fig. 16.

A Monœcious Plant.

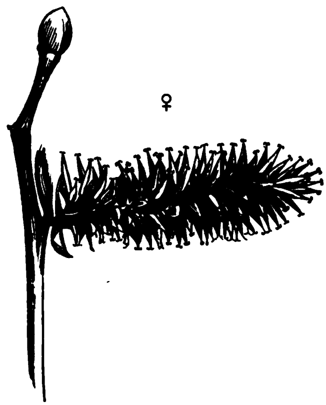
When staminate and pistillate flowers grow upon separate plants (Figs. 18 and 19), such plants are said to be *diœcious.* Fig. 17 represents a pistillate flower from the female catkin (Fig. 18). Fig. 20 represents a staminate flower from the male catkin (Fig. 19).

These catkins grow upon different trees; so the willow from which they were taken is *diœcious.*

Fig. 17.

Pistillate Flower, from Catkin (Fig. 18).

Fig. 18.



Female Catkin of a Diœcious Plant.

Fig. 19.

Male Catkin of a Diœcious Plant.

Fig. 20.

Staminate Flower, from Catkin (Fig. 19).

When staminate, pistillate, and perfect flowers are all found upon the same plant, it is *polygamous.*

Point out upon the charts examples of monœcious, diœcious, and polygamous plants.

Let the pupil answer the following questions concerning each flower of his collection:

Is your flower symmetrical or unsymmetrical?

Is it complete or incomplete?

Is it dichlamydeous, monochlamydeous, or achlamydeous?

Is it perfect or imperfect?

Did it grow upon a monœcious, diœcious, or polygamous plant?

Monœcious—From two Greek words, signifying *single* and *house*, having the stamens and pistils in distinct flowers, but both growing upon the same plant.

Diœcious—From two Greek words, signifying *two*, or *double*, and *house*, having the stamens on one plant and the pistil on another.

Polygamous—From two Greek words, *polus*, many, and *gamos*, marriage, having both perfect and imperfect, or diclinous, flowers.

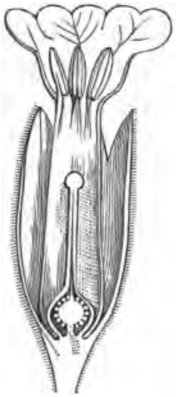
EXERCISE VII.

Form of the Receptacle and Insertion of Floral Organs.

INSERTION.—In botanical language, organs are said to be *inserted* at the place from which they apparently arise. For instance, in Fig. 21 it will be seen that the pistil is inserted upon the receptacle, the stamens are inserted upon the corolla, the corolla is inserted

upon the receptacle, and the calyx also is inserted upon the receptacle.

FIG. 21.



Look at the magnified flowers shown in section on chart 1, and point out the receptacle in each case. Are all these receptacles alike in form? State, in regard to each flower, where the pistil is inserted; where the stamens; where the corolla; and where the calyx. Which floral whorl in each flower occupies most space upon the receptacle? Are these flowers perfect? Are they complete? Are they symmetrical?

Repeat these observations upon the magnified flowers shown in section in chart 2; in charts 3, 4, 5, 6.

Make a longitudinal section of each of your living flowers, and look for the insertion of the floral organs. If you sometimes fail to discover it, do not be discouraged. It will not, of course, be as clearly visible as it is shown to be on the chart. Try again another time. Make frequent attempts, as failure is often due to lack of experience.

EXERCISE VIII.

On Polyandrous Stamens.

We now take up the study of the flower at just the point where it was left in "The First Book of Botany." While using that book you learned the names of the floral organs, and observed their number. You also examined the calyx and corolla to learn whether or not their parts were grown together. If the sepals were not grown together, the calyx was described as *polysepalous*, and, if they were grown together, it was said to be *gamosepalous*. So, also, when the petals of the corolla were distinct, the corolla was said to be *polypetalous*, and, when grown together, *gamopetalous*.

We will proceed to an examination of the essential organs in this respect.

Gather all the flowers you can find, and observe the *stamens*, to see if they are grown together. Put aside all that have united stamens, whatever their degree of union.

Now inspect the flowers with distinct stamens, and put by themselves all that have more than twelve.

A flower with more than twelve distinct stamens is said to have its stamens *indefinite*.

They are *definite* when there is a fixed number not above twelve.

Separate those with indefinite stamens, and label them *polyandrous* (from *poly*, many, and *andria*, stamens), which means many distinct stamens.

Now examine the flowers with definite stamens, and label each one with the name that, in the follow-

ing table, is placed opposite its number of stamens. The Greek numeral prefix denotes the number of distinct stamens:

Mon-androus—one stamen.	Hept-androus—seven stamens.
Di-androus—two stamens.	Oct-androus—eight stamens.
Tri-androus—three stamens.	Enne-androus—nine stamens.
Tetr-androus—four stamens.	Dec-androus—ten stamens.
Pent-androus—five stamens.	Dodec-androus—twelve stamens.
Hex-androus—six stamens.	

Poly-androus—more than twelve.

Like the word polyandrous, these terms apply only to distinct stamens; at the same time they have the important advantage of giving the precise number.

But, if a tetrandrous flower has two stamens long and two short (Fig. 22), it is said to be *didynamous*,

FIG. 22.

Didynamous Stamens.

FIG. 23.

Tetradynamous Stamens.

and, if an hexandrous flower has four stamens long and two short (Fig. 23), it is said to be *tetradynamous*.

These words, applied to the stamens of a flower,

give at the same time their number, the fact that they are distinct, and the proportion of long to short ones.

Can you find upon the charts any flowers with tetradynamous stamens? Have any of them didynamous stamens?

EXERCISE IX.

The Growing together of Stamens.

Having disposed of all your flowers with distinct stamens, next examine those with united stamens.

First observe whether they have grown together by their filaments, or by their anthers. All those having their anthers united, whether into a tube, around the pistil, or in any other way, may be put together and labelled *syngenesious* (Figs. 25 and 26).

FIG. 24.

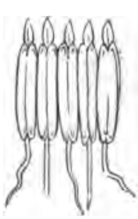
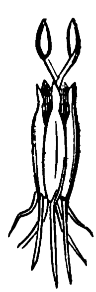


FIG. 25.



Syngenesious Stamens.

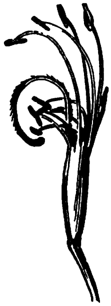
FIG. 26.

Syngenesious Stamens.

Fig. 24 shows this tube laid open. Those that have grown together by their filaments have to be further studied. Are all the filaments grown together in one bundle? If so, the stamens are *monadelphous* (Fig. 27).

Are they grown together in two bundles? Then they are *diadelphous* (Fig. 28).

FIG. 27.



Monadelphous Stamens.

FIG. 28.

Diadelphous Stamens.

Are they in three or more bundles? Then we say they are *polyadelphous* (Figs. 29 and 30). In Fig. 29 one bundle is cut away.

FIG. 29.

Tri- or Polyadelphous.

FIG. 30.

Polyadelphous.

The number and length of the hard words in this exercise may embarrass the pupils, but a little use will make them familiar, and they will then greatly help the process of description.

Collect all the plants in the neighborhood, from garden, road-side, fields, and woods, and in describing their stamens you will become well acquainted with all the necessary terms.

Syngenesious (*sun*, Gr., together; *genesis*, origin).
Monadelphous (*monos*, Gr., one; *adelphos*, brother).
Diadelphous (*dis*, Gr., twice).
Polyadelphous (*polus*, Gr., many).

EXERCISE X.

The Growing together of Carpels.

You have been accustomed to counting the carpels of flowers, and you are now to find whether or not they are grown together.

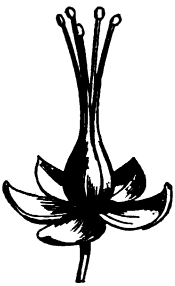
All such as are not grown together at all you may label *apocarpous* (Fig. 31).

FIG. 31.

Apocarpous Pistil.

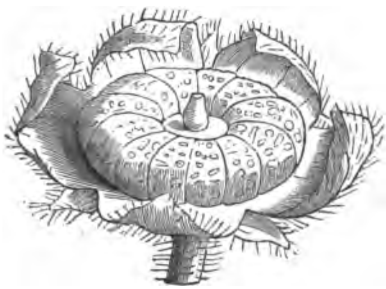
Those that are grown together, whether slightly at the base of the ovary or through the whole length of the pistil, you label *syncarpous* (Figs. 32 and 33).

FIG. 32.



Syncarpous Pistil.

FIG. 33.



Syncarpous Pistil.

Find all the apocarpous ovaries pictured upon the charts. All the syncarpous ones.

Find also the apocarpous ovaries in your collection of flowers. The syncarpous ones.

For this exercise, faded flowers, and even those that have lost their floral leaves, will serve better than such as are freshly opened.

Apocarpous (*apo*, Gr., apart; *karpos*, fruit).
Syncarpous (*sun*, Gr., together; *karpos*, fruit).

COHESION.—In botany this word is used for the growing together of parts with their fellows, as of petals with petals, carpels with carpels. Figs. 38 and 42 illustrate this.

We now resume the use of the schedule in its application to the examination and description of flowers.

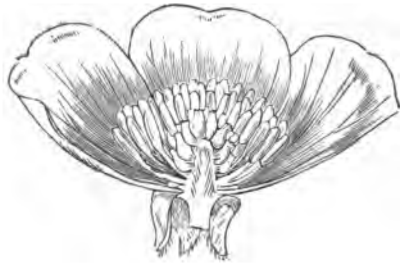
The last schedule given in "The First Book"

had the word *description* written over its third column, and under this title could be placed all kinds of observations. But, as in this book we enter upon more careful and minute work, we shall be much aided in arranging our discoveries by adopting the plan of Prof. Henslow, who places the word *cohesion* above this column, and devotes it to observations upon the cohesion of parts in flowers.

Fig. 34 represents half a buttercup. It has been sliced down through the middle, making what is called a vertical section of the flower, that you may see the structure of the stamens and pistil. This flower is used for the first schedule because of its simplicity, its parts being all quite distinct from each other. It is without cohesion, and, in describing it, you have to use terms which apply to distinct stamens and carpels.

The learner will, of course, provide himself with a real flower, and fill out a schedule from his own examination of it. The buttercup is easily found, for it grows almost everywhere, and blossoms throughout the summer. I must insist that the pupil be not content with simply looking over the description in the book. The example is given, not as a substitute for your own effort, but as a means of testing your observations; of letting you know whether your own way of carrying out the schedule description is the correct one. Any lack of confidence you may feel in beginning a new process will disappear upon finding that your own observations and expressions agree with the printed ones. A schedule or two thus employed, when you are beginning to use new terms, will assist you in gaining self-reliance.

FIG. 34.



Schedule First, describing Fig. 34, gives this arrangement:

SCHEDULE FIRST.

Organs.	No.	Cohesion.
Calyx? *Sepals.*	5	Polysepalous.
Corolla? *Petals.*	5	Polypetalous.
Stamens?	∞	Polyandrous.
Pistil? *Carpels.*	∞	Apocarpous.

Questions upon the Buttercup (Fig. 34) *and Schedule First.*

Is there cohesion in the calyx?
What word in the schedule expresses this?
Is there cohesion in the corolla?
How is this stated in the schedule?
Are the stamens definite or indefinite?

Are they grown to each other?

What word in the schedule answers this question?

Do the carpels cohere?

How is this expressed?

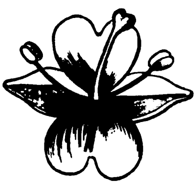
Questions reviewing the Subject of Cohesion in the Parts of a Flower.

What is meant by cohesion in botany?

How do you describe a calyx with no cohesion (Fig. 35)? A corolla (Fig. 37)? Stamens (Exercise VIII.)? Pistil (Fig. 41)?

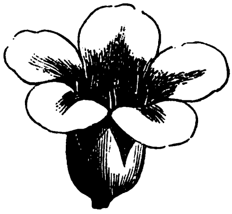
When the sepals are coherent, how do you describe the calyx (Fig. 36)? The corolla (Fig. 38)?

FIG. 35.



Polysepalous, no Cohesion.

FIG. 36.



Gamosepalous, coherent.

When stamens cohere by their anthers, what word do you use in describing them (Figs. 24, 25, and 26)?

When, by their filaments in one bundle, what word is used (Fig. 27)?

In two bundles (Fig. 28)?

In three or more bundles (Figs. 29 and 30)?

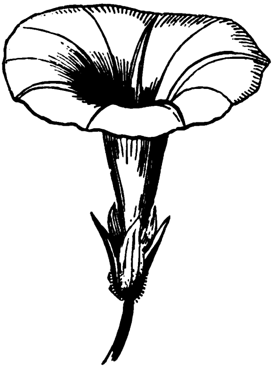
How do you describe a coherent pistil (Fig. 42)?

There are a few common flowers found everywhere in the country, in which there is no cohesion; but, in most flowers, the parts of some of the floral circles will be found more or less united.

Fig. 37.

Polypetalous, no Cohesion.

Fig. 38.



Gamopetalous, coherent.

Fig. 39.

Polyandrous, Stamens not coherent.

Fig. 40.

Triadelphous, Stamens coherent.

Fig. 41.

Apocarpous, no Cohesion.

Fig. 42.

Syncarpous, coherent.

Figs. 43, 44, and 45 represent the flower of the Saint-John's-wort. Fig. 44 is a vertical section of the flower, and Fig. 45 one of the bundles of stamens.

Fig. 43.

Fig 44.

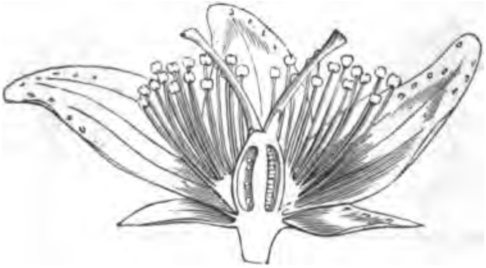
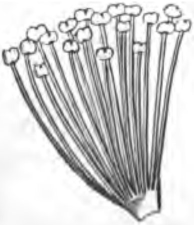


Fig. 45.



Schedule Second, describing Fig. 44, is an example where cohesion of stamens and pistil is described.

SCHEDULE SECOND.

Organs.	No.	Cohesion.
Calyx ? *Sepals.*	5	Polysepalous.
Corolla ? *Petals.*	5	Polypetalous.
Stamens ?	∞	Tri- or Polyadelphous.
Pistil ? *Carpels.*	3	Syncarpous.

By turning to page 48 you will see that another column is there added to the schedule. After three more exercises, which introduce new observations and new terms, this addition becomes necessary. Your attention is called to it now, to give urgency to the advice that you make diligent use of the present schedule in describing all kinds and degrees of cohesion in all sorts of flowers. If you do this, when the time comes to add this third column, your mind will be free to attend to the new features that belong to it. The terms expressing cohesion being familiar, there will be no confusion of thought, and you will enter upon the new observations with ease and pleasure.

Fig. 46.

SCHEDULE THIRD.

Organs.	No.	Cohesion.
Calyx ? *Sepals.*	5	Polysepalous.
Corolla ? *Petals.*	5	Polypetalous.
Stamens ?	10	Monadelphous.
Pistil ? *Carpels.*	5	Syncarpous.

EXERCISE XI.

Union of Floral Whorls with each other—Calyx and Pistil.

In your study of fruits ("First Book of Botany," Ex. LXVII.) did you always find the calyx at the base of the ovary ?

Have you ever seen upon the apex of ripened fruit the withered calyx, or the scar left by its fall ?

Point out upon the charts all the cases where the calyx is below the ovary.

Point to those where the calyx is above it.

Is the calyx in all the pictures upon the chart either at the base or at the apex of the ovary ?

For this exercise select flowers that have their parts so well developed that you can see distinctly

where each organ is inserted. Take, for example, the morning-glory, and observe whether the calyx arises below the ovary or not. If you find it is inserted below the ovary, label it calyx below, or *inferior* (Fig. 47), and lay it aside. If the calyx is inserted above the ovary, label it calyx above, or *superior* (Fig. 48). Of course, if the calyx is below the

FIG. 47.

Inferior Calyx.
Superior Ovary.

FIG. 48.

FIG. 49.

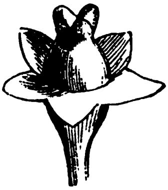
Superior Calyx.
Inferior Ovary.

ovary, or *inferior*, the ovary will be above the calyx, or *superior*; and, when the calyx is *superior*, the ovary will be *inferior*.

Examine all your flowers in the same way, giving each its proper label. If some specimens have the calyx inserted neither at the bottom nor at the top

of the ovary, but somewhere along its side (Fig. 50), you describe these as having the calyx half inferior, and the ovary half superior.

FIG. 50.



Calyx, half inferior.—Ovary, half superior.

NOTE.—When the calyx seems to be inserted at the top of the ovary (Fig. 48), you are to regard it as *really* inserted on the receptacle, but as having its tube grown to the ovary, and so appearing to be inserted at its summit. The words *superior* and *inferior* came into use before the real relation of the parts was understood. The true expression is "calyx adherent to ovary," in place of calyx superior; and "calyx free from ovary," in place of calyx inferior. But the words superior and inferior are in general use, and, being short, are retained in schedule description.

EXERCISE XII.

The Union of Floral Whorls with each other.—Corolla.

You are now to determine the insertion of the corolla.

Compare the arrangement of parts in each of your flowers with that shown in Fig. 51, and, when you

find the corolla inserted below the ovary, and free from the calyx, label the specimen corolla, *hypogynous.*

FIG. 51.

Corolla, hypogynous (Gray).

Examine the remainder of your flowers, and, when you find one with the corolla inserted, as shown in Fig. 52, say corolla upon the calyx, or *perigynous.*

FIG. 52.

Corolla, perigynous (Gray).

How is the corolla inserted in Fig. 53? Point out upon the charts where the corolla has a similar insertion.

Look at the flowers not yet described, and, if you find cases where the corolla is inserted upon the ovary, describe them as *epigynous,* from *epi,* upon, and *gynia,* pistil (Fig. 53).

FIG. 53.

Corolla, epigynous.

If not quite certain about these characters in your specimens, write your label with a mark of interrogation, to show doubt. Do not be discouraged if these points of structure remain for some time troublesome ones to discover. Try to find them out, and, if you succeed, it is well; but, if not, it is well also.

As some flowers upon the same plant are more perfectly developed than others, you should gather several of each kind, and examine them all, to find the best examples of the structure you are studying.

Look at the flowers in chart 1, and observe in each case whether the corolla arises from the receptacle, and whether the calyx is free from the corolla.

Find upon the other charts all the cases where the corolla is inserted under the ovary, and is free from the calyx.

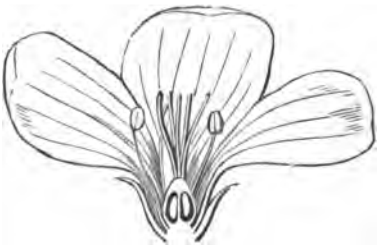
Observe the flowers on chart 2. Where is the corolla inserted in these figures? Can you find upon the other charts any pictures of flowers where the corolla has a similar insertion?

EXERCISE XIII.

Union of Floral Whorls with each other—Stamens.

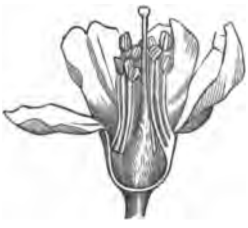
If the stamens have the same insertion as the corolla, use the same words to describe them. For instance, in Fig. 54 the stamens are *hypogynous;* in Fig. 55, *perigynous;* in Fig. 56, *epigynous.*

FIG. 54.



Stamens, hypogynous.

FIG. 55.



Stamens, perigynous.

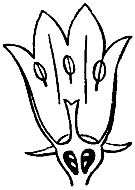
FIG. 56.

Stamens, epigynous.

When you find them arising from the corolla, as seen in Fig. 57, they are said to be *epipetalous.*

Sometimes they are consolidated with the pistil, as shown in Fig. 58; then they are *gynandrous*, or upon the pistil.

FIG. 57.



Epipetalous Stamens.

FIG. 58.

Gynandrous Pistil.

Examine all the flowers you can find, and label them by the insertion of the stamens; as, stamens under the ovary, or *hypogynous;* stamens upon the calyx, or *perigynous;* stamens upon the ovary, or *epigynous;* stamens upon the corolla, or *epipetalous;* stamens consolidated with the pistil, or *gynandrous*.

Adhesion in botany means the growing together of different floral whorls, while *cohesion*, as you have seen, means the growing together of the parts of the same whorl.

The word *free* is used to express absence of adhesion, and the word *distinct*, absence of cohesion.

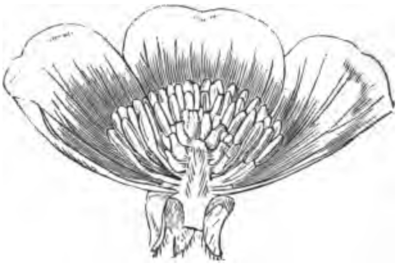
In Fig. 59 there is neither cohesion nor adhesion.

FIG. 59.

Parts, *distinct*.—Organs, *free*.

Not only are the sepals and petals *distinct* from each other, not only is each stamen and each carpel *distinct*, but the whorl of sepals is inserted upon the receptacle, and is *free* from the whorls within it. The corolla is inserted upon the receptacle, and is also *free*. The stamens and pistil are also inserted upon the receptacle, and are likewise *free*.

Fig. 60.



The last column of Schedule Fourth is for the record of observations on adhesion.

Schedule Fourth.

Organs.	No.	Cohesion.	Adhesion.
Calyx? *Sepals.*	5	Polysepalous.	Inferior.
Corolla? *Petals.*	5	Polypetalous.	Hypogynous.
Stamens?	∞	Polyadelphous.	Hypogynous.
Pistil? *Carpels.*	3	Apocarpous.	Superior.

Questions upon the Buttercup (Fig. 60) *and its Schedule.*

Is the calyx free or adherent?
How is this expressed in the schedule?
Where is the corolla inserted?
How is this stated in the schedule?
Are the stamens free or adherent?
Where are they inserted?
How is this expressed in the schedule?
Is the pistil free or adherent?
How is this written in the schedule?

We have now reached the complete schedule of Prof. Henslow, which he called the flower-schedule, and which was used by his classes both at Cambridge University and at his parish school at Hitcham. Complaints have been made that it was difficult. Pupils who commence its use before they fully understand the features of plants to which it calls attention, will, no doubt, get confused when they attempt to fill up the blanks one after another, but those who have examined a variety of flowers, in connection with the foregoing pages, will have no such trouble.

The presence or absence of cohesion and adhesion in flowers is of great importance in determining the relationships of plants, and scholars cannot do better than continue the use of this schedule throughout the summer season, along with the making of an herbarium. Do not fail to fill out schedules of the following flowers, from your own observation. Never write a word of description unless it be of something your own eyes have seen, and that you could point out to any one who might contradict you.

Be careful not to copy statements from the book. I have known cases where the book was made wrong on purpose to mislead unwary and indolent scholars.

FIG. 61.

Fig. 61 represents a flower of cow-parsnip. That of the carrot, or any umbelliferous plant, will do as well.

We give some further examples of the use of the schedule in flowers of very unlike structure.

SCHEDULE FIFTH.

Organs.	No.	Cohesion.	Adhesion.
Calyx? *Sepals.*	5	Gamosepalous.	Superior.
Corolla? *Petals.*	5	Polypetalous.	Epigynous.
Stamens?	5	Pentandrous.	Epigynous.
Pistil? *Carpels.*	2	Syncarpous.	Inferior.

Fig. 62 shows a vertical section of the flower of daffodil. It is common enough in gardens; but, if there are pupils who can get neither this flower, nor the jonquil, nor the snow-drop, they can certainly find a lily of some kind, wild or cultivated, and observe the features in which it is unlike this picture.

FIG. 62.

SCHEDULE SIXTH.

Organs.	No.	Cohesion.	Adhesion.
Perianth? *Leaves.*	6	Gamophyllous.	Superior.
Stamens?	6	Hexandrous.	Perigynous.
Pistil? *Carpels.*	3	Syncarpous.	Inferior.

Fig. 63 is a blossom of wild geranium. Figs. 64 and 65 are the stamens and pistil of the same. The flower of the garden geranium will serve in its place, if it can be more easily obtained. In Fig. 70 this pistil is again shown.

FIG. 63.

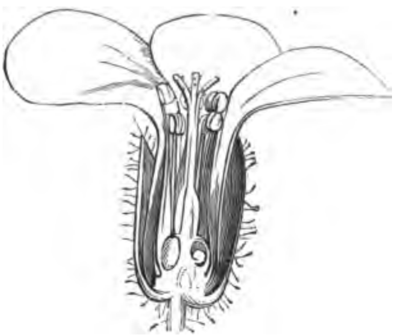


FIG. 64.

FIG. 65.

SCHEDULE SEVENTH.

Organs.	No.	Cohesion.	Adhesion.
Calyx ? *Sepals.*	5	Polysepalous.	Inferior.
Corolla ? *Petals.*	5	Polypetalous.	Hypogynous.
Stamens ?	10	Decandrous.	Hypogynous.
Pistil ? *Carpels.*	5	Syncarpous.	Superior.

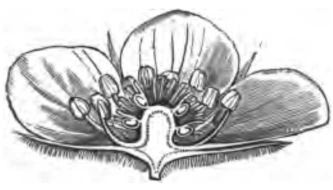
EXERCISE XIV.

The Receptacle.

The peculiarities of plants pointed out in this and the following exercise are not very common. But pupils who are using the flower-schedule, and collecting all the plants they can find, will be sure to meet with examples of them sooner or later. These exercises should, therefore, be carefully read, and borne in mind, so that, when the features they describe are met with, they may be recognized.

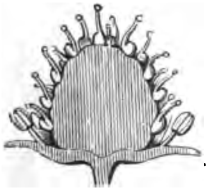
Before passing to the more minute observation of the floral organs, the receptacle requires further study. You have seen it forming a central convexity, like that of Fig. 66, and gradually expanding into a structure like Figs. 67 and 68. Sometimes the re-

FIG. 66.



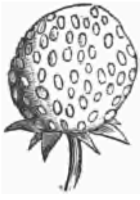
Convex Receptacle.

FIG. 67.



Receptacle, enlarged, and shown in Section.

FIG. 68.

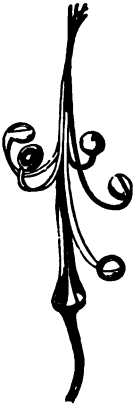


The same, fully developed.

ceptacle is prolonged between the carpels, and coheres with their styles, which separate from it at maturity, as seen in Figs. 69 and 70 (Gray).

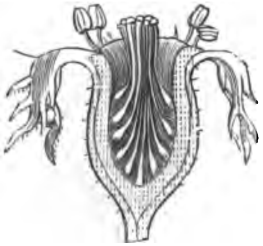
FIG. 69.

FIG. 70.



It sometimes appears as a cup-shaped depression (Fig. 71), in which the pistil is almost concealed, and again as shown in Fig. 72.

FIG. 71.



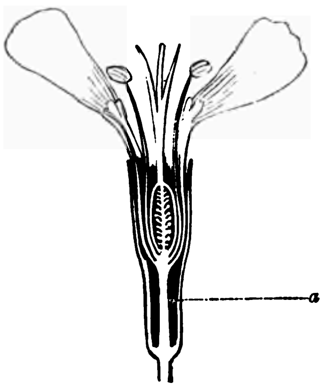
Cup-shaped Receptacle.

FIG. 72.

Elevated Fleshy Receptacle.

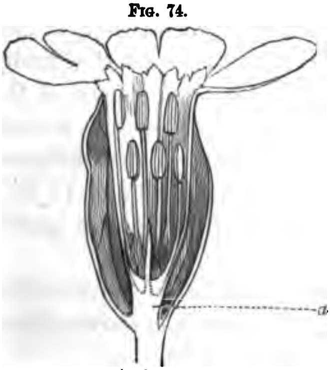
Whenever the receptacle becomes elongated, so that one circle of floral organs is separated from another by a stalk-like internode, the circle thus raised is said to be *stipitate*, and the stalk supporting it is called a *stipe*. In Figs. 73 and 74, the stamens, pistil, and corolla, are *stipitate*, and the stalk which bears them is the *stipe*.

FIG. 73.



a, Anthophore.

FIG. 74.



a, Anthophore.

FIG. 75.

b, Gonophore; *c*, Gynophore, Gynobase, or Carpophore (Gray).

When the stipe supports corolla, stamens, and pistil, it is called an *anthophore* (Fig. 73). When it supports only stamens and pistil, it is known as the *gonophore* (Fig. 75, *b*); the *gynophore*, *gynobase*, or *carpophore*, when it bears the pistil alone (Fig. 75, *c*).

Thalamus—The receptacle of the flower, or the part of the peduncle into which the floral organs are inserted.

Torus—Another name for thalamus.

Receptacle (*recipio*, I receive).

Thalamus—A bed.

Torus—A couch.

EXERCISE XV.

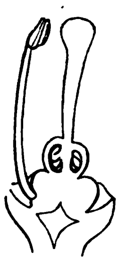
Appendages of the Receptacle.

Examine the receptacle in the magnified flowers upon charts 1, 2, 3, and 4.

Carefully observe the space between the calyx and ovary in the figures opposite. You see a sort of fleshy cushion at the base of the ovary in one case, at the base of the style in another. The raised rim around the pistil is called a *disk*. It takes on very different shapes in different plants. In Figs. 76 and 77 it is merely a raised cushion; in Fig. 78 it is seen partly enclosing the ovary.

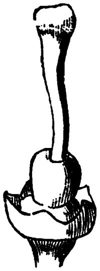
In Figs. 79 and 80 the disk is seen surrounding the ovary, while in Figs. 81 and 82 it is shown above the ovary, and at the base of the style.

FIG. 76.



Hypogynous Disk.

FIG. 77.

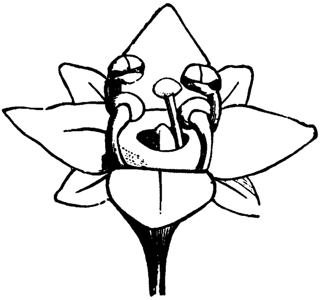


Hypogynous Disk.

FIG. 78.

Hypogynous Disk.

FIG. 79.

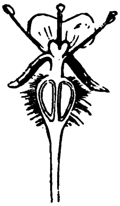


Perigynous Disk.

FIG. 80.

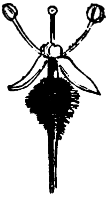
Perigynous Disk.

FIG. 81.



Epigynous Disk.

FIG. 82.



Epigynous Disk.

The little glands upon the receptacle are known as *nectaries*. They contain sweet fluids, and are found among the stamens (Figs. 83 and 84), or at the base of the pistil, forming a part of the disk (Figs. 85, 86, and 87).

FIG. 83.

FIG. 84.

FIG. 85.

FIG. 86.

FIG. 87.

CHAPTER II.

COMPARING AND CLASSIFYING PLANTS.

EXERCISE XVI.

Plant Characters and Affinities.

You are now to take a step forward in the study of plants. Having acquired considerable knowledge of their parts by direct observation, you will begin to compare them — to note their resemblances and differences as wholes, and, by these resemblances, to

arrange, or group, them in a systematic way. This is classification.

You have been doing something of the kind ever since you commenced observing plants. For instance, those with parallel-veined leaves have been classed by themselves, and those with flowers in umbels have been associated together, and kept distinct from such as blossom in heads or in panicles; but your groupings have thus far been made upon single features of plants, as was inevitable in the beginning of study. You are now prepared to grasp at once in thought more parts of structure, and make your comparisons more full and complete.

If, for example, you have put into one group all square-stemmed plants, simply because they have square stems, it is time to consider whether these plants are alike in other features. "Oh, yes," some of you will say, "they have opposite leaves." Well, look at their inflorescence; do they all agree in that? Is it always axillary? Are the flowers similar in all the square-stemmed plants you know? When you have answered these questions, you will understand what I mean by studying plants as wholes.

And now, how shall you set to work?

First, provide yourself with the following plants: The buttercup (which is found almost everywhere), the wild-columbine, and the poppy. If the columbine is not to be found, get monk's-hood, or larkspur, or anemone, and proceed with them in the way pointed out for the columbine. If the poppy cannot be found, you might substitute blood-root, or celandine. Having got the plants, proceed according to the plan laid down, and do not accept the statements or con-

clusions of the book, unless, on comparing them with your own plants, you see that they are true.

There are two botanical expressions, of which, at the outset, you should learn the meaning. One of these is *the characters of plants*, and the other *the affinities of plants*. And, first, what is meant by *plant-characters?*

If you will describe a buttercup, I think we can easily find just what is meant.

You say, "CALYX, *sepals*, 5, polysepalous, inferior; COROLLA, *petals*, 5, polypetalous, hypogynous; STAMENS, many, hypogynous; PISTIL, *carpels*, many, apocarpous, superior." Yes; but what about the rest of the plant? You answer: "It has simple, exstipulate, alternate, divided leaves; petiole spreading at base; stem, erect; flowers, in a loose cluster; juice, watery, acrid.

Now, this is the description of a particular buttercup, and yet it applies to all buttercups. Are all buttercups, therefore, exactly alike? By no means. They differ in size, shape, thriftiness, number of blossoms, etc.; but, in our botanical description, we do not record these individual peculiarities.

Well, the points of form and structure in which all buttercups agree, that is, their *permanent features*, are called by botanists the *characters* of the buttercup. All such unchanging features of plants are *plant-characters.* A plant is simply an assemblage of characters, and the description of a plant is but a list of its characters.

Now, it is by comparing groups of characters that we reach the idea of *affinities.* If, as we have seen, each plant bears a fixed group of characters, the re-

semblance of one plant to another is only the resemblance of one group of characters to another. Let us make such a comparison between the buttercup and columbine.

Do not rely upon the descriptions in the book, but make similar tables yourself.

BUTTERCUP.—*Flower.*	COLUMBINE.—*Flower.*
Calyx.—Sepals, 5, polysepalous, inferior.	*Calyx.*—Sepals, 5, polysepalous, inferior, colored like the petals.
Corolla.—Petals, 5, polypetalous, hypogynous, obcordate, yellow.	*Corolla.*—Petals, 5, polypetalous, hypogynous, spurred, red.
Stamens.— ∞, hypogynous.	*Stamens.*— ∞, hypogynous.
Pistil.—Carpels, ∞, apocarpous, superior.	*Pistil.*—Carpels, 5, apocarpous, superior.

Comparing the above lists, you see agreements and differences. The calyx and corolla of one plant agree with those of the other in number of parts and in the position of parts. They differ only in color and outline. The stamens of one are like those of the other in being numerous and hypogynous. The pistils agree in structure, but differ in the number of carpels. If you compare the leaves, stems, inflorescence, etc., you also get a list of their resemblances and differences. This is comparing plants by the groups of characters they present.

These resemblances of character among plants are called their affinities.

The *degree* of affinity between plants depends upon two circumstances: first, upon the *kind* of

characters in which they agree; and, second, upon the *number* of characters in which they agree.

The characters of plants differ in importance. Such kinds of character as color, size, and odor, being usually more variable than such kinds as position, size, and number, they are said to be less important than these. The characters of the leaf, for the same reason, are not usually as important as the characters of the flower. In the beginning of study, you may safely assume that those plants are most alike, have the strongest *affinities*, that resemble each other most in the characters recorded in the cohesion and adhesion columns of the schedule.

To make this plainer, compare the poppy and buttercup, as, before, you compared the columbine and buttercup.

BUTTERCUP.	POPPY.
Calyx.—Sepals, 5, polysepalous, inferior.	*Calyx.*—Sepals, 2, polysepalous, inferior.
Corolla.—Petals, 5, polypetalous, hypogynous.	*Corolla.*—Petals, 4, polypetalous, hypogynous.
Stamens.—Polyandrous, hypogynous.	*Stamens.*—Polyandrous, hypogynous.
Pistil.—Carpels, many, apocarpous, superior.	*Pistil.*—Carpels, many, syncarpous, superior.
Leaves.—Net-veined, divided.	*Leaves.*—Net-veined, divided.
Juice.—Watery.	*Juice.*—Milky.

To find which has the strongest affinity for the buttercup, the columbine, or the poppy, all that is necessary, at present, is, to ascertain which of them is nearest like the buttercup in respect to cohesion and adhesion of the parts of the flower.

On examination, you see that the columbine, like the buttercup, is perfectly destitute of cohesion, while in the poppy you have a coherent, or syncarpous, pistil. This settles the question. The affinity of the columbine for the buttercup is greater than that of the poppy.

If you compare their leaves, you will find those of the poppy more like buttercup-leaves than are those of the columbine, but differences in leaf-structure do not usually signify as much in classification as differences in the pistil.

Compare, in the same way, the hollyhock and the Saint-John's-wort with mallows, and decide which has the strongest affinity for the mallows.

Compare the flower of the locust and of the geranium with that of the pea or bean.

I mention these plants, not because they are useful above all others for your purpose, but to start you in the work. It really matters little what plants you take, if you only carefully compare the group of characters of each one with that of the others, and endeavor to discover the affinities they present.

EXERCISE XVII.

How to begin Classification.

If you have made the comparisons pointed out in Ex. XVI., you are prepared for an explanation of the plan by which you are to begin to classify plants. As

we made use of the buttercup and columbine to learn the meaning of *affinity* in botany, a little further statement about them will, perhaps, be helpful before we pass to the regular work of the exercise.

The buttercup is said to be more thrifty, more at home in low, damp places. It is like frogs in this respect; and, because of this, it is named after them. Its botanical name is *Ranunculus*, from *Rana*, a frog. The Ranunculus has certain characters with which you are familiar. Now, when you find other plants which are very much like it, that is, which present nearly the same group of characters, particularly those of cohesion and adhesion, you class them with it, you say they belong with the buttercup; or, in more botanical language, they belong to the Ranunculaceæ. In some regions this plant, from the form of its leaf, is called the Crowfoot, and plants closely resembling it are said, therefore, to belong to the Crowfoot family. Now, the resemblance of the columbine to the buttercup entitles it to belong to the Ranunculaceæ. The monk's-hood and larkspur also belong to the same family, and this will give you some idea of the degree of similarity that should exist between members of one family.

Our object in the present exercise is, to fix upon a method by which to begin the work of classifying plants, by comparing the groups of characters they present, and putting together those that are most alike.

Get a pocket note-book. Write in it, boldly and plainly, the flower-schedules of the following plants: Buttercup, shepherd's-purse, mustard or radish, catch-

fly, mallows, Saint-John's-wort, clover, pea or bean, wild-rose, strawberry, geranium, violet, morning-glory.

Now, why have we put these particular schedules into the note-book? Compare them with each other. Do you not see that the statements in the cohesion and adhesion columns are widely unlike? This is why we have chosen them. They are so many different patterns of the make-up of flowers, and you have simply to compare each flower you describe with one and another of these patterns, to see which is the best fit. If none of them fit at all, then set up your new acquaintance as another pattern, and see if you can find any of its relations in the course of the summer. So, do not confine yourself to comparisons between your specimens and the patterns in your note-book. Compare them freely with each other, and you will soon have many little collections of plants bearing very strong resemblances to each other.

Your thought will be something like this: While you are observing and describing a plant, you will ask yourself, "Have I ever before described one like it in the matters of cohesion and adhesion?" If you can think of none, you will try to recall those nearest like it. By pursuing this plan, you will be surprised to find how quickly many of the plants of a region, that were never before thought of as at all alike, fall into company on the ground of these deeper resemblances which your studies have led you to discover.

The reason why you are set systematically to classifying plants now, and have not been asked to do it before, is, that among the characters of plants that

belong to roots, leaves, stems, etc., there are none that are so uniform throughout large numbers of different plants as these features of cohesion and adhesion in flowers. Since you began to observe plants, you have not been taught to notice any points of structure that would serve so well for uniting plants into groups, the members of which are truly and somewhat nearly related to each other.

But the grounds on which you are to begin to classify plants, although important, and, in many cases, quite sufficient, are not the only ones on which classification is based. Though they may sometimes be found too narrow, yet you must begin somewhere, and, to make your beginning as free as possible from complexities, you start with the features named in the flower-schedule. In working with this, much of your experience will be clear and satisfactory, but you may meet with difficulties. By-and-by, however, the subject will be resumed, and, if you have sometimes been confused and puzzled in classifying by the flower-schedule alone, new ideas will be all the more welcome.

Students who have the botanical charts will find them very helpful in the work of classification. Upon these charts there are pictured in the colors of Nature some forty pattern-plants, magnified, and shown in section, so that their structure is easily seen. These plants have been selected because the differences they present are just those broad contrasts that separate groups of plants in Nature. At this stage of your study, while your thoughts are confined to the features of the flower-schedule, the first, second, third, and fifth charts present pattern-plants of all varieties

in these respects. Their great value to the pupil, in classification, at the beginning of study, lies in the distinctness of the idea he gets from them as to how his pattern-plant is constructed.

The work of classification being now entered upon, it will be resumed, from time to time, with further explanations as we proceed, particularly when we come to study such groups of plants as the grains and grasses, the cone-bearing plants, the Compositæ, familiarly known as compound flowers, the Umbelliferæ, etc. These striking natural orders will introduce us to new principles in judging of affinities, and pupils who are specially fond of this part of the study, and are apt in tracing resemblances, will do well to look over the chapters upon these plants without waiting to reach them in the course of regular study.

NOTE.—There is often, among both teachers and pupils, an aversion to skipping about. The idea of thoroughness with them seems to imply moving steadily on from page to page of a book, without ever deviating from its order. But in such a science as botany it is not necessary to proceed in this way. The subject cannot be marked off sharply into parts that must be learned in a certain order. Of course, plant characters must be known before they can be used in classification; but, when a few are known, they may be at once put to service. A pupil cannot do better than to acquaint himself with the group of cruciferous plants as soon as the special characters that belong to this group are familiar. Any group of plants may be classified as soon as the characters upon which it is founded are fairly known. To get a knowledge of classification requires much time, and its study should, therefore, be commenced at the earliest possible moment.

There is another reason for skipping about, which will be at once appreciated. It is this: Plants have their time to flower, and their flowers must be studied at that time. For

CHAPTER III.

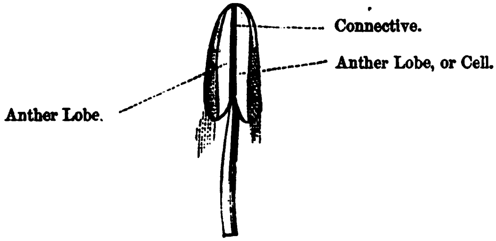
THE STAMENS.

EXERCISE XVIII.

Parts of Stamens.

COMMENCE this exercise by examining the parts of a well-formed stamen. Select, for this purpose, a flower with stamens having large anthers. If they have not yet shed their pollen, all the better. Compare this anther with Fig. 88, and look for the parts pointed out in the picture.

FIG. 88.



---

example: the Coniferæ blossom in spring, and spring is the time to study them. Stamens may be found throughout the entire season, and so may be studied at any time. It would be folly, therefore, to let the period pass in which the Coniferæ might be studied, because you "hadn't come to them" in the book, and pursue the study of stamens because they are next in order. Again, the characters of orchids are illustrated by a plant which has its season, and the time to study orchids is when this plant makes its appearance.

Do you see in your specimen a groove down the middle of the anther on one of its sides? Is there any thing like a ridge on the other side of the anther, opposite the groove?

Can you divide the anther at this place without coming upon the pollen?

What name is given to this part of the anther in Fig. 88? What are the two halves it connects called?

Look at your living anther for the line along each lobe, called the line of dehiscence in the figure.

What name is given in Fig. 89 to the sides of the anther-cells? (Of course, each lobe has two valves; but, as they are opposite, only one can be shown in a picture.)

ANTHER-LOBE.—The cell which holds the pollen (Fig. 88).

CONNECTIVE.—A continuation of the filament which unites the two lobes of the anther. It is often inconspicuous or absent, but is sometimes easily seen (Fig. 88).

VALVES.—The sides of an anther-lobe.

LINE, OR POINT, OF DEHISCENCE.—The opening through which the pollen escapes.

It may help the learner in forming a distinct idea of these different parts of the anther, to know that the stamen is looked upon by botanists as a sort of leaf, the filament answering to the petiole, and the anther to the blade. The connective corresponds to the mid-rib of a leaf, and the line of dehiscence to its margin, each lobe being half of a leaf-blade, and

the valves of an anther corresponding to the upper and under sides of a leaf.

Examine the anthers of as many different flowers as possible, and try to find the cells, connective, line of dehiscence, valves.

Do not be disappointed or discouraged if, in many cases, you fail to distinguish some of the parts.

Look at the magnified stamens on the charts, and find, if you can, the parts of the anther named in this exercise.

EXERCISE XIX.

Number and Shape of Anther-Lobes.

NUMBER OF ANTHER-LOBES.

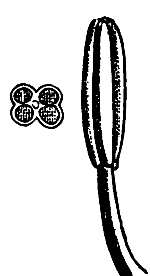
FIG. 90.

One-celled Anther.

FIG. 91.

Two-celled Anther.

FIG. 92.



Four-celled Anther.

SHAPE OF ANTHER-LOBES.

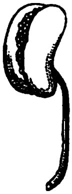
FIG. 93.

Arrow-shaped Anther.

FIG. 94.

Oblong Anthers.

FIG. 95.



Kidney-shaped Anther.

FIG. 96.

Emarginate Anthers.

FIG. 97.

Sinuous Anthers.

EMARGINATE.—When the summit, or base, of the anther-cell extends upward or downward, a little beyond the connective (Fig. 96).

Label each flower of your collection with the number and shape of the anther-cells of its stamens.

Find, if you can, upon the charts instances of one-celled anthers, of two-celled anthers, of four-celled anthers. Mention the form of each anther-lobe pictured upon the charts.

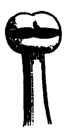
EXERCISE XX.

Dehiscence of the Anther.

FIG. 98.

Vertical, or Longitudinal.

FIG. 99.



Transverse.

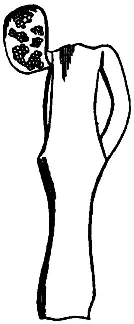
FIG. 101.

Porous.

FIG. 102.

Valvular.

FIG. 103.



Valvular.

VERTICAL, OR LONGITUDINAL DEHISCENCE.—When the anther opens by a slit along its length to emit the pollen (Fig. 98).

TRANSVERSE.—When the line of dehiscence is across the anther (Fig. 99).

POROUS.—When the anthers emit the pollen through little pores (Fig. 101).

VALVULAR.—When a portion of the anther is lifted up to emit the pollen (Figs. 102 and 103).

In describing the stamens of flowers you will now observe the kind of dehiscence the anther exhibits.

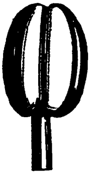
Name the various modes of dehiscence of anther-cells shown upon the charts.

EXERCISE XXI.

Introrse and Extrorse Anthers.

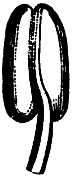
When the valves of the anther are of equal size, the dehiscence will occur laterally (Fig. 106); but, if one valve be wider than the other, it will throw the line of dehiscence nearer to the connective on one side than on the other. The narrowed valves are usually on the projecting side of the anther-cell, and this is called the *face* of the anther (Fig. 104).

FIG. 104.



Face.

FIG. 105.



Back.

The other side, where the connective is usually visible, if seen at all, and where the filament is attached in most cases, is called the *back* of the anther (Fig. 105).

NOTE.—The projecting side of the anther-cell is called its *face*, and the opposite side is called its *back*, whether the valves are unequal or not.

FACING THE PISTIL.

FIG. 106.

Lateral Dehiscence.

FIG. 107.

Introrse Anthers.

Anthers are INTRORSE when the line of dehiscence, or face of the anther, is toward the pistil.

FACING THE COROLLA.

FIG. 108.

Extrorse Anthers.

FIG. 109.

Extrorse Anthers.

Anthers are EXTRORSE when the line of dehiscence, or face of the anther, is turned toward the corolla (Figs. 108 and 109).

Look over the charts for examples of extrorse and introrse anthers. In future observe the stamens of living flowers with reference to this feature.

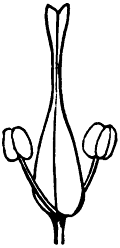
EXERCISE XXII.

Attachment of Filament to Anther.

Fig. 111.

Innate.

Fig. 112.



Innate.

Innate.—Anthers are *innate*, or *basifixed*, when the filament runs directly into the base of the connective (Figs. 111, 112, and 116).

Adnate.—Anthers are *adnate*, or *dorsifixed*, when the filament runs up the back of the anther, joining the connective in such a way that the anther is hung in front of it (Figs. 113 and 114).

Versatile.—If the filament is attached by a slender apex to the middle of the anther, the ends of which swing freely up and down, the attachment is said to be *versatile* (Fig. 115).

FIG. 113.

Adnate.

FIG. 114.

Adnate.

FIG. 115.

Versatile.

FIG. 116.

Basifixed.

FIG. 117.

Dorsifixed.

FIG. 118.

Apsifixed.

The modes of attachment, pictured and named above, shade into each other, so that, in practice, it is often difficult to determine them. The versatile passes into the adnate, and the adnate into the innate, and a nice exercise of judgment is sometimes needed in describing this feature of flowers.

Find these several modes of attachment on the charts. Determine and describe the mode of attachment in each of your living specimens.

EXERCISE XXIII.

Forms of Filaments.

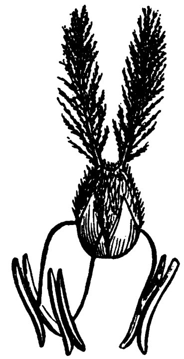
Fig. 122.

Filiform.

Fig. 123.

Sub-ulate.

Fig. 124.



Capillary.

Filiform filaments are thread-like, as the name denotes, but strong enough to support the anther (Fig. 122).

Sub-ulate filaments taper like an awl (Fig. 123).

Capillary filaments are hair-like, and too slender to support the anther (Fig. 124).

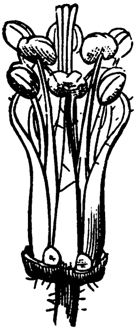
Dilated filaments are flattened out like Fig. 126.

Petaloid filaments resemble petals in form, and bear the anther at the summit, as seen in Figs. 127 and 128.

Bi-dentate, or Bi-cuspid, filaments are toothed at the summit or at the base, as seen in Figs. 129 and 130.

Find examples of the several kinds of filaments upon the charts. Describe the different forms of filaments in your collection of plants.

FIG. 125.



Dilated.

FIG. 126.

FIG. 127.

Petaloid.

FIG. 128.

Bi-dentate.

FIG. 129.

Bi-dentate.

EXERCISE XXIV.

Structure and Forms of Pollen.

The pollen-grain is generally composed of two membranes, or coats, filled with a thick liquid substance containing minute grains, which is its essential portion. The outer coat is frequently marked with bands, lines, and grooves, or covered with bristling points (Fig. 131). The inner coat is very thin, and swells when wetted. If you moisten pollen-grains, you may often see, with a microscope, the expanded inner coat protruding through openings in the outer coat (Fig. 131).

EXTINE.—The outer coat of a pollen-grain, usually with openings, or very thin in certain places (Figs. 131, 132, and 133).

INTINE.—The inner coat of a pollen-grain, very

thin, tough, and elastic, often seen protruding through holes in the extine (Figs. 132 and 133).

Fovilla.—The rich protoplasmic liquid contained within the intine (Fig. 133).

Fig. 131.

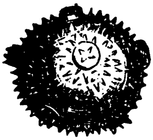


Fig. 132.

Fig. 132*.

Fig. 133.

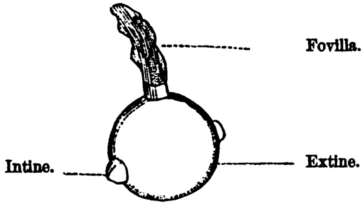
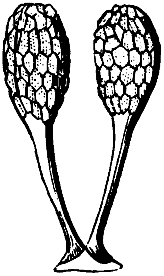


Fig. 134.



Polinia.

Polinia.—Pollen-grains cohering in masses. In Fig. 134 they are in pairs, and are furnished with stalk-like processes; but in some plants they are single, and without a stalk.

Fig. 135.

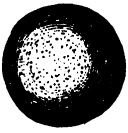


Fig. 136.

Pollen-grains display a great variety of shapes. Besides the round and oblong (Figs. 135 and 136), you will find them angular, lobed, and joined together in various ways (compound pollen) by threes, fours, and even larger numbers (Fig. 132).

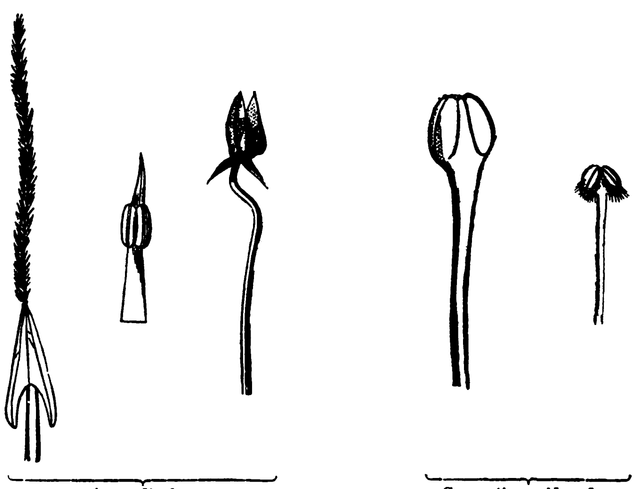
Look at the various forms of pollen pictured upon the charts.

Examine the pollen of flowers with your magnifying-glass, and note the shape of the grains, and the kind of surface they present. Observe the moistened pollen of various plants under the microscope.

EXERCISE XXV.

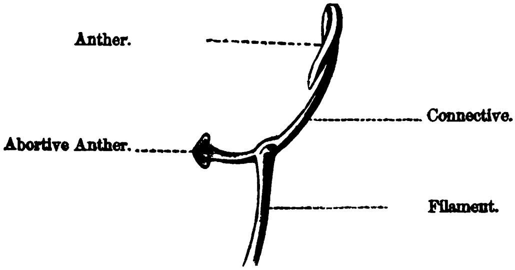
Forms of Connective.

FIG. 137. FIG. 138. FIG. 139. FIG. 140. FIG. 141.



Appendicular. Connective, widened.

FIG. 142.



Dimidiate.

APPENDICULAR.—When the connective, extending above or below the anther, takes the form of a feather, or a lengthened point, or a fleshy mass, or spur-like appendages, or stipules (Figs. 137, 138, and 140).

When one lobe of an anther is abortive, or suppressed, the anther is said to be *dimidiate*. Fig. 142 represents a dimidiate anther and a connective developed into arms, so that the lobes are entirely disconnected.

Observe the abortive anther-lobe of Fig. 142. The entire stamen, as well as each of its parts, is liable to suppression, abortion, or imperfect development. The symmetry of flowers is often destroyed in this way. In some plants the non-development of organs that exist in the rudimentary state is a constant character, and should be regarded in describing them.

Observe the figures on the chart which illustrate these forms of connective. Look over the flowers of your collections, and in future describe the form of connective when you can distinguish it.

EXERCISE XXVI.

General Features of Stamens.

FIG. 143.

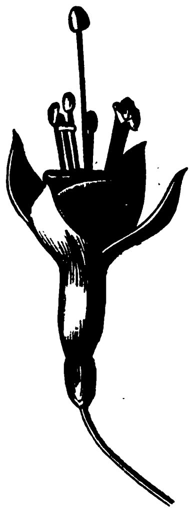
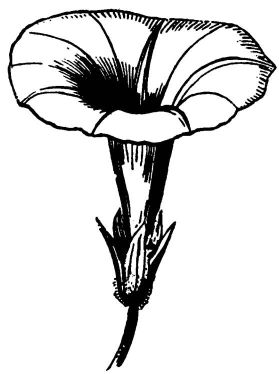


FIG. 144.



EXSERTED.—Stamens are said to be *exserted* when they extend beyond the corolla (Fig. 143).

INCLUDED.—When the stamens are not as long as the corolla, they are said to be *included* (Fig. 144).

The entire whorl of stamens is called the *andrœcium.*

When the filament is wanting, the anther is described as *sessile.*

When the anther is wanting, the stamen is said to be *sterile.*

Converging stamens are said to be *connivant.*

In observing and describing stamens, the following schedule will be found useful by calling attention to the several characters pointed out in the present chapter:

Stamen Schedule.

Parts?
Number of anther-lobes?
Shape of anther-lobes?
Attachment of filament and anther?
Facing?
Form of filament?
Form of pollen?
Form of connective?
General features?

Adnate (Lat., *adnascor*, I grow to)—Grown fast to, or formed in union with, another body.

Appendicular (Lat., *appendo*, I hang up)—Having an appendage.

Basifixed (Lat., *basis*, the base)—Attached by the base.

Dimidiate (Lat., *dimidiatus*, halved)—Appearing as if one half were wanting.

Dorsifixed (Lat., *dorsum*, the back)—Fixed upon the back.

Extrorse (Lat., *extra*, externally; *orsus*, originating)—Turned outward.

Fovillæ (Lat., *foveo*, I nourish)—Minute particles in the fluid contained in pollen.

Innate (Lat., *innatus*, inbred)—Borne directly on the apex of a thing.

Intine (Lat., *internus*, internal)—The inner lining of pollen-grains.

Introrse (Lat., *introrsus*, inwardly)—Turned toward the axis.

Subulate (Lat., *subula*, an awl)—Awl-shaped.

Versatile (Lat., *versatilis*, that turns easily)—Swinging to and fro.

CHAPTER IV.

THE PISTIL.

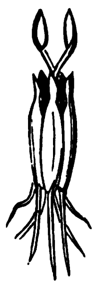
EXERCISE XXVII.

Kinds of Stigma.

FIG. 144.

Sessile and Lateral.

FIG. 145.



Bifid.

FIG. 146.

Trifid.

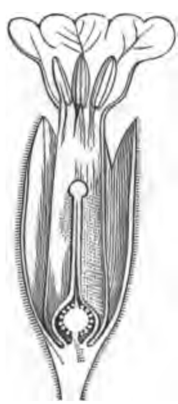
FIG. 147.

Trifid.

FIG. 148.

Scrolled.

FIG. 149.



Globose.

FIG. 150.

Lobed.

EXERCISE XXVIII.

Form and Position of Styles.

FIG. 155.

Sigmoid.

FIG. 156.

Lateral.

FIG. 157.

Basal.

FIG. 158.

Terminal

The shapes of styles may be named by the same words as the shapes of filaments.

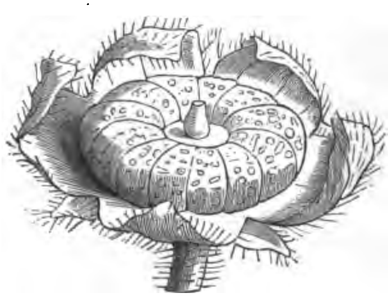
Observe, in faded flowers and young fruit, whether the styles are persistent or deciduous.

EXERCISE XXIX.

Kinds of Pistil.

It will be convenient to apply the following names to certain distinctions among pistils with which pupils are now familiar:

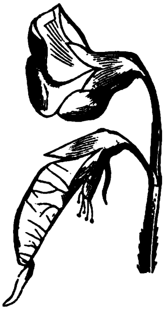
FIG. 159.



A Compound Pistil.

A COMPOUND PISTIL (Fig. 159) consists of several united carpels—is *syncarpous.*

Fig. 160.

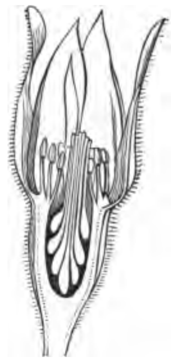


A Simple Pistil.

Fig. 161.

Multiple Pistil.

Fig. 162.



Multiple Pistil.

A Simple Pistil (Fig. 160) consists of only a single carpel, and is, of course, *apocarpous.*

A Multiple Pistil (Figs. 161 and 162) consists of several distinct carpels—is also *apocarpous.*

EXERCISE XXX.

The Structure of Ovaries.

Whether a pistil is simple, multiple, or compound, each carpel may be looked upon as a single leaf. The simple pistil of the pea, for instance, may be regarded as the blade of a leaf folded at the midrib, so that its inner portion answers to the upper face of a leaf, and its outer portion to the under face. Its dorsal suture will correspond to the midrib, and its ventral suture to the margin of the leaf.

To make this plainer, take any strong oblong leaf (Fig. 163), and fashion it into a carpel, like the pea-pod, taking the upper part of the leaf for the inner

part of the carpel. Fold in the margins slightly to represent the placentæ (Fig. 164). (See "First Book," Ex. LXVIII.) If the fold will not stay in place, take a stitch or two along it with a needle and thread. Now double it at the midrib (Fig. 165), and compare it with a pea-pod. Find the valves; the dorsal and ventral portions; the stigma; the base.

FIG. 163.

FIG. 164.

FIG. 165.

Gather some old, faded pea-blossoms, in which the ovary is somewhat enlarged, and observe that the ventral suture is turned inward; that is, it lies along the central line, or axis, of the flower. It is along this axis, then, that the double placentæ are formed. Observe the position of the dorsal suture, or back of the pod. It is important to bear in mind that, in the case of the simple pistil, the ovules are attached centrally along the axis of the flower.

Roughly to imitate a multiple pistil, you have only to bind together, by their petioles, several leaf-blades that have been converted into carpels, as above. Observe the placentation of any multiple pistil, and you will invariably find that the placenta of each carpel is central in the same way that, in the artificial one, you have made the margins of your carpellary leaves turn inward, and the midribs outward.

After thus preparing simple and multiple pistils from foliage leaves, let us try to construct a compound pistil from leaf-blades. If we can do this, it will give us a clear understanding of the structure of syncarpous ovaries.

Form, from foliage leaves, an artificial ovary, of three coherent carpels. A three-celled compound pistil consists of three carpellary leaves grown together. It is as if, by pressing together the carpels of your multiple pistil, they should unite by their sides. To make an artificial compound pistil, then, you have only to select three large symmetrical foliage leaves, and pin or stitch them together in such a way that their margins will meet in the centre, and their under surfaces will form its outer wall. If you cannot get leaves of firm texture that will hold a pin or stitch without tearing, try lining them with some thin cloth or paper. Fold each of the leaves at the midrib, with the upper surface inward, as seen in Fig. 166. Fasten the left half of one leaf-blade to the right half of another, so that the united portions will form a double wall between the cells, and the six edges will meet together at the centre, as represented in Fig. 167.

Your aim being simply to understand how, and from what, each part of a compound pistil is formed, you need not care for the clumsiness or shapelessness of your manufactured ovary.

Point out its cells. Its dissepiments. Explain why they are double. Point out the dorsal and ventral suture of each carpel of your syncarpous structure. Where should you look for ovules in this pistil?

FIG. 166.

FIG. 167.

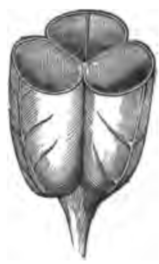


FIG. 168.

Prepare a compound ovary by joining three leaves at their margins, as seen in Fig. 168. In what part of an ovary so formed are the leaf-margins? In what part of the ovary would you look for the ovules? The theory of the pistil is important, because it gives clear ideas of the varied and complex characters of ovaries; and these characters are of the first importance in classification.

EXERCISE XXXI.

Placentation.

After studying the structure of ovaries as explained in Ex. XXX., the following definitions will be easily understood:

PLACENTATION.—The arrangement of placentæ is called *placentation.*

To determine the mode of placentation of a plant, slice its ovary across, and compare its appearance with the following figures. The formation and arrangement of placentæ are so various, that we have given an unusual number of drawings to illustrate the definitions.

AXILLARY PLACENTATION.—When the ovules are found along the central line, or axis of the pistil, the placentation is called *axillary*, or *axile* (Figs. 169, 170, 171, 172, and 173).

FIG. 169.

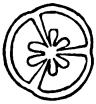


FIG. 170.

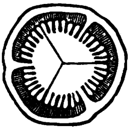


FIG. 171.

FIG. 172.

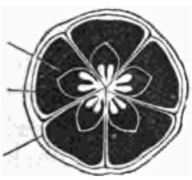


FIG. 173.

Free-Central Placentation.—When the dissepiments, or double partitions, between the cells are absent, leaving the placentæ and ovules at the centre, and all the cells opening into one chamber, the placentation is said to be *free-central* (Figs. 174, 175, 176, and 177).

Fig. 174.

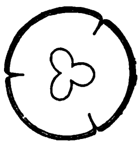


Fig. 175.

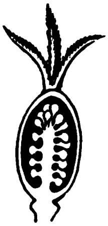


Fig. 176.

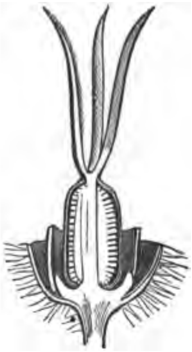


Fig. 177.

Parietal Placentation is seen when the placentæ are attached to the walls, or projections from the walls, of the ovary, as is illustrated in the following figures (178–185):

Fig. 178.

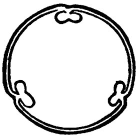


Fig. 179.

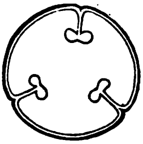


Fig. 180.

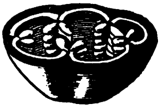


Fig. 181.

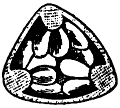


Fig. 182.

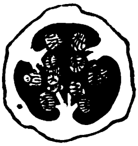


Fig. 183.

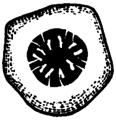


Fig. 184.

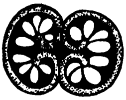
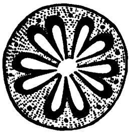


Fig. 185.

False Dissepiments.—It will be well to know that, in many ovaries, there are partitions not formed in the way described in Ex. XXX. The following are instances of what are known as false dissepiments:

Fig. 186.

Fig. 187.



Observe in Fig. 186 a partition going inward from the dorsal suture, and nearly reaching the centre of the flower.

Fig. 187 shows a similar false partition not quite so much extended.

Fig. 188.

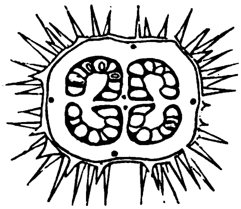


Fig. 189.

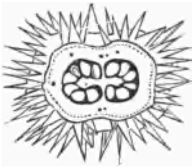


Fig. 190.

Fig. 188 is a section across the middle of an ovary, and Fig. 189 is a section across the upper part of the same ovary. The partitions that appear in one and are not seen in the other, must be false—they cannot be formed by the sides of adjacent carpels.

In Fig. 190 the placentæ are parietal, but a membrane is formed, reaching across the ovary, and forming a false dissepiment. These false dissepiments, you see, are developed, in some cases, from the dorsal suture; in others, from the placentæ.

It may sometimes be difficult to decide between true and false dissepiments; but, as your knowledge of plants increases, the different members of the same group will often be found to afford transitional characters that make evident what otherwise would be uncertain.

EXERCISE XXXII.

Modes of Dehiscence.

To understand the modes of dehiscence, pictured in this exercise, you have only to prepare a three-celled compound ovary, as directed in Ex. XXX.,

observing the place of the dorsal and ventral sutures, the relations of the valves, and that the partitions are double.

REGULAR OR VALVULAR DEHISCENCE.—Dehiscence is said to be valvular when the ovary separates into the regular pieces called valves.

FIG. 191.

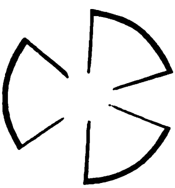
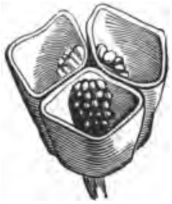


FIG. 192.

FIG. 193.



The dehiscence is SEPTICIDAL when the ovary splits through the partitions, each dissepiment separating into its two layers, one belonging to each carpel (Figs. 191, 192, and 193).

FIG. 194.

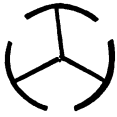


FIG. 195.

The dehiscence is LOCULICIDAL when the splitting opens into the cells by the dorsal suture, as seen in Fig. 195, which represents the ovary of a violet, where

the carpels flatten out as soon as they are released from each other.

Fig. 196.

Fig. 197.

Septifragal.

Fig. 198.

The dehiscence is Septifragal where the valves fall away, leaving the dissepiments behind attached to the axis (Figs. 196 and 197).

Irregular Dehiscence.—Seeds are sometimes discharged through chinks, or pores (porous dehiscence) (Fig. 198), or the ovary may burst in some part irregularly.

Now compare the capsules in your collection with the figures and definitions given in this exercise, and determine, if you can, the mode of dehiscence of each of them.

How would you produce loculicidal dehiscence in the compound ovary you have made with leaves, as directed in the opening of this exercise?

How septicidal? How septifragal?

EXERCISE XXXIII.

Direction of Ovules and Seeds.

Ovules have an *horizontal* direction when they are neither turned upward nor downward, as in Figs. 199 and 200. They are *ascending* when rising obliquely upward, as in Fig. 201.

FIG. 199.

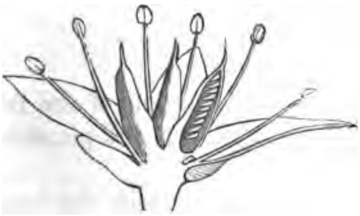


FIG. 200.

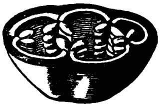
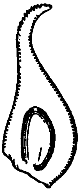


FIG. 201.



Ovules are said to be *erect* when rising upright from the base of the cell (Fig. 202). They are *suspended* when hanging perpendicularly from the summit of the cell (Fig. 203). They are *pendulous* when hanging from near the top (Fig. 204).

FIG. 202.

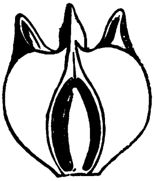


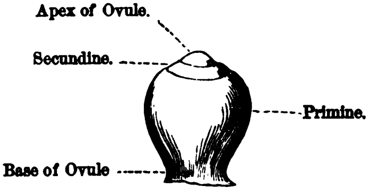
FIG. 203.

FIG. 204.

EXERCISE XXXIV.

Parts of the Ovule.

FIG. 205.



BASE OF OVULE.—The point of union of the funiculus and ovule; not of the funiculus and placenta (Fig. 205).

APEX.—The part of the ovule opposite the base (Fig. 205).

PRIMINE.—The outer sac of an ovule (Fig. 205).

SECUNDINE.—The inner sac of an ovule (Fig. 205).

These parts are again shown in Figs. 206 and 207, along with others that appear when we make a section of the ovule.

FIG. 206.

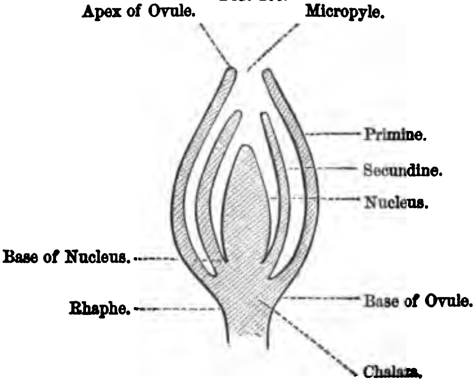
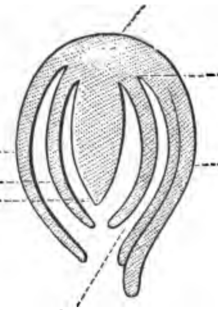


FIG. 207.



MICROPYLE.—The opening in the coats of an ovule, or seed (Figs. 206 and 207).

NUCLEUS.—The substance contained within the sacs, in which the embryo is formed (Figs. 206 and 207).

RHAPHE.—The connection between the base of the nucleus and the base of the ovule. In Fig. 206 the rhaphe is short, and concealed within the ovule, but in Fig. 207, where the position of the nucleus is so changed as to bring its base round to the apex of the ovule, the rhaphe is visible, and extends along one side, still connecting the base of the nucleus with the base of the ovule.

CHALAZA.—The place where the coats and nucleus grow together.

HILUM.—The scar left by the separation of a seed from its placenta.

It is not supposed that pupils will find all these parts of the ovule in plants. Some of them are usually discernible, and they may all be understood in their proper relations by studying the diagrams.

EXERCISE XXXV.

Kinds of Ovule.

FIG. 208.

Straight, or Orthotropous.

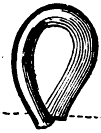
FIG. 209.

Curved, or Campylotropous.

The STRAIGHT, or ORTHOTROPOUS OVULE, has the base of the nucleus and the base of the ovule in the same position, while the micropyle is at the apex (Fig. 208).

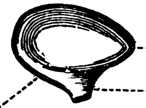
In the CURVED, or CAMPYLOTROPOUS OVULE, the micropyle, or apex, is bent over close to the base (Fig. 209).

FIG. 210.



Inverted, or Anatropous.

FIG. 211.



Half-inverted, or Amphitropous.

In the INVERTED, or ANATROPOUS OVULE, the funiculus lengthens, and bends round, growing fast to the coat, until the base of the nucleus is at the apex of the ovule (Fig. 210).

In the HALF-INVERTED, or AMPHITROPOUS OVULE, the funiculus only lengthens till the ovule turns a quarter of the way over, as in Fig. 211.

(The pupil is referred to page 118, the close of the chapter on fruit, for a list of questions—a sort of pistil-schedule—to be used as a guide in describing this organ.)

Amphitropal (Gr., *amphi*, about; *trepo*, I turn).

Anatropal (Gr., *ana*, over; *trepo*, I turn)—An ovule turned over, so as to bring the micropyle to the hilum.

Axile (Lat., *axis*, an axle-tree)—Belonging to the centre, or axis.

Campylotropal (Gr., *campulus*, curved; *trepo*, I turn)—An ovule, or seed, bent so as to bring the apex near to the hilum.

Chalaza (Gr., a spot on the skin)—The place in a seed where the nucleus joins the integuments.

Dehiscence (Lat., *dehisco*, I gape)—Splitting into parts.

Dissepiment (Lat., *dissepio*, I separate)—Partitions in a fruit.

Hilum (Lat., the black scar of a bean)—The scar left by the separation of a seed from its placenta.

Loculicidal (Lat., *loculus*, a cell)—A mode of dehiscence through the back of a carpel.

Micropyle (Gr., *mikros*, small; *pulē*, gate)—The scar in the skin of a seed, which was the foramen in the ovule.

Nucleus (Lat., a kernel)—The centre of an ovule, where the embryo is formed.

Orthotropal (Gr., *orthos*, straight; *trepo*, I turn)—An erect ovule, with the foramen or micropyle opposite the hilum.

Parietal (Lat., *paries*, a wall)—Growing to the walls of an ovary.

Placentation (Lat., *placenta*, a cheese-cake)—The way the placentæ are developed.

Primine (Lat., *primus*, first).

Rhaphe (Gr., *rhaphe*, a seam)—The thread connecting the placenta and nucleus.

Secundine (Lat., *secundus*, second).

Septicidal (Lat., *septum*, a hedge; *cædo*, I cut)—A mode of dehiscence dividing the dissepiment.

Septifragal (Lat., *septum*, a hedge; *frango*, I break)—A mode of dehiscence where the valves fall away from the dissepiment.

CHAPTER V.

THE FRUIT AND SEED.

EXERCISE XXXVI.

The Composition of Fruit.

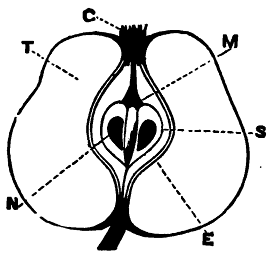
FRUIT.—The ripened ovary, with its contents, is the fruit of plants. Whatever adheres to the ovary also becomes part of the fruit.

In studying fruit, observe with care what parts, besides the pistil, have been concerned in its formation. In describing flowers, you note whether the pistil is inferior or superior; is there any reason to suppose that inferior fruit would be most likely to have other parts of the flower besides the pistil united with it? Did you observe the flowers of the cherry, plum, or peach trees, and those of apple and pear trees when they were in blossom? and if so, will you compare your recollection of them with the appearances presented by their fruit? If you have forgotten their structure, perhaps you have kept a description of them, and can refresh your memory.

Observe the ripe fruit of the cherry. Look at the top of the peduncle for scars left by the parts of the fallen flower. Look for a dot at the top of the fruit, showing the place of the style. Has any thing but the pistil entered into the formation of this fruit? Observe the plum, peach, grape, currant, etc., and see if they are like the cherry in these respects.

Now examine an apple or pear. What do you find at the top of the fruit, opposite the peduncle? It must be the remains of the calyx-limb, the tube of which you saw united to the pistil when you studied it in flowering-time. Of what, then, does the fruit consist? Divide an apple or pear, as shown in Fig. 212. Find the parts shown in this diagram. The re-

FIG. 212.



mains of the flower are seen at C. The calyx-tube, grown fleshy and succulent, is marked T. The outer border of the ovary is seen at E. From what part of the flower is the eatable portion of a pear or apple developed? To repeat our former question, would the fruit of a superior pistil be more likely than that of an inferior pistil to consist of the ovary alone?

I have illustrated the composition of fruit with apples and cherries because they are so common; but these observations may, and should be, repeated upon every variety of fruit that can be found.

Trace the formation of each of the fruits pictured upon the charts, and point out those that consist of the pistil alone, and those which do not. In the latter case, name the parts that are consolidated with the pistil in the fruit.

When fruit is formed from the pistil alone, the wall of the ovary is called a *pericarp* (from *peri*, around).

Gather specimens of every kind of fruit that grows within reach. In late summer or early autumn, the fruit of garden, field, and forest, if carefully collected, will give you a large and various assortment. For example: you may have at the same time cucumbers, melons, beans, peas, grapes, apples, pears, elder and pokeweed berries, chestnuts, walnuts, pumpkins, etc., and the less conspicuous seed-vessels of mullein, Saint-John's-wort, lettuce, radish, cabbage, etc., etc. Earlier in the season the list will be different, and it will vary somewhat with the locality, but, wherever collected, and whatever its components, be sure to gather every kind that can be had.

Look over your collection, and separate the superior from the inferior fruits. Observe the structure of those formed from inferior pistils, and point out the pericarp in those formed from superior pistils.

Preserve, for further study, the specimens you have gathered.

EXERCISE XXXVII.

Parts of the Pericarp.

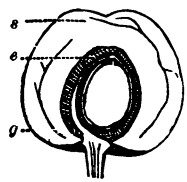
EPICARP.—When the walls of a pericarp are formed of two or more layers of different texture, as in the peach, plum, or cherry, the outer one (the skin, in the case of these fruits) is called the *epicarp*.

ENDOCARP.—The stony case around the seed of the

peach, plum, or cherry, is called the *endocarp*. But the endocarp of fruits is not always stony. Whatever its texture, the inner layer of a pericarp is named the endocarp.

MESOCARP.—Sometimes, between the outer and inner parts of a pericarp, there is found a third layer of different aspect, like the pulp of a peach. This third layer is called the *mesocarp*. The distinction between the epicarp and mesocarp is often very slight, and then both together are called the *epicarp*.

FIG. 213.



In Fig. 213 *e* is the endocarp, *s* the mesocarp, and *g* the epicarp.

In Fig. 212 E is the epicarp, N the endocarp, and S the seeds. At N is shown a slight development of the mesocarp. Point out these parts in an apple and a peach. Point out the parts of the pericarp in the different fruits pictured upon the charts.

Classify your collection of fruits by the structure of the pericarp. Put by themselves all those that have but one layer in the pericarp. Put those with two layers—an epicarp and endocarp—by themselves, leaving those with three layers—epicarp, mesocarp, and endocarp. Describe the layers that make up the fruit; that is, say whether, in each case, the layer is pulpy, woody, stony, membranous, leathery, etc.

Preserve your collection for further study, and add to it all you can get.

EXERCISE XXXVIII.

The Classification of Fruit.

Look over your collection and separate the dehiscent from the indehiscent fruits. The indehiscent group may now be further separated into juicy fruits and dry fruits. Compare your specimens of juicy fruit, one by one, with the following pictures and definitions of fruits. The first picture is that of a berry; so you may first find the berries of your collection. To determine whether a particular fruit is a berry or not, cut it across, and see if it agrees in structure with Fig. 214, and the requirements of the definition. Never mind whether your conclusion accords with common speech or not; whether a strawberry turns out to be a berry or not; but follow the definition wherever it leads.

Indehiscent Juicy Fruits.

BERRY.—A thin-skinned, indehiscent, fleshy fruit, having the seeds embedded in the pulpy mass (Figs. 214 and 215).

FIG. 214.

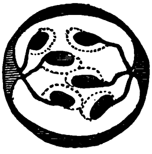
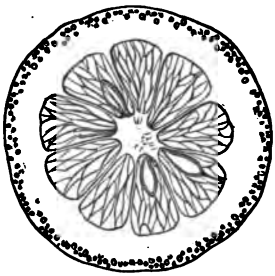


FIG. 215.

HESPERIDIUM.—A kind of berry with a leathery rind (Fig. 216). (Example, lemon and orange.)

FIG. 216.



PEPO.—The pepo is an indehiscent, fleshy fruit, with seeds borne on parietal placentæ, and with the epicarp more or less thickened and hardened. (Example, squash.)

POME is the term applied to a fleshy, indehiscent, several-celled fruit, with a leathery, or cartilaginous, endocarp, enclosed by the calyx-tube. Figs. 217 and 218 are transverse and vertical sections of a pome. (Example, apple and pear.)

FIG. 217.

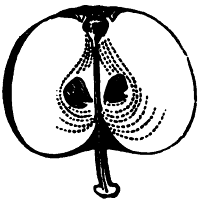
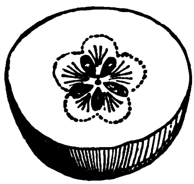


FIG. 218.



DRUPE (example, peach or cherry) is a pulpy, indehiscent, one-celled, one or two seeded fruit, with a succulent or fibrous epicarp, and hard, stony, distinct endocarp (Figs. 219 and 220).

FIG. 219.

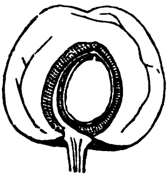


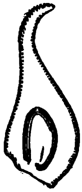
FIG. 220.

If you have blackberries, raspberries, and the like, among your fruits, compare one of the little cells that make up this kind of fruit with this definition of a drupe.

Indehiscent Dry Fruits.

Select from among your dry indehiscent fruits all those that resemble Figs. 221, 222, 223, and 224, and that are usually miscalled seeds. You will find upon many of them such appendages as hairs, teeth, plumes, bristles, etc.

FIG. 221.



Vertical Section of Carpel of Buttercup.

FIG. 222.

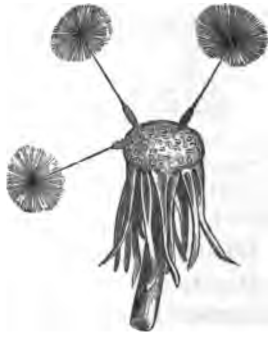


FIG. 223.

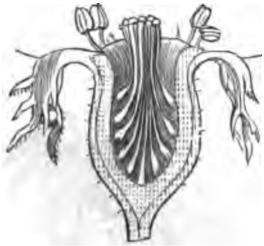
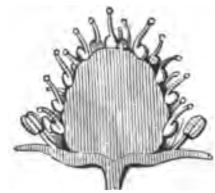


FIG. 224.



They are achenia. An ACHENIUM is a dry, indehiscent, one-seeded fruit, with a separable pericarp, tipped with the remains of the style (Figs. 222–224).

UTRICLE.—By this term is understood a kind of achenium, with a thin, bladdery pericarp which is sometimes dehiscent.

FIG. 225.

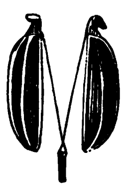
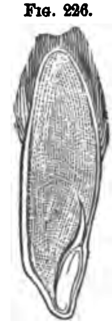


FIG. 226.



CARYOPSIS.—A dry, indehiscent, one-celled, one-seeded fruit, with the pericarp adherent to the seed, as seen in wheat, barley, oats, maize, etc. (Fig. 226).

CREMOCARP.—Pendant achenia. (Sée Ex. LII).

CYPSELA.—Still another variety of achenium,

with an adherent calyx-tube, as in compositæ (Fig. 222).

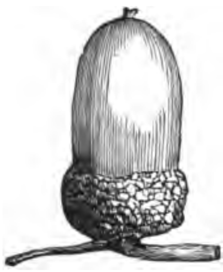


Fig. 227.

Fig. 228.

Nut.—A hard, one-celled, one-seeded, indehiscent fruit, produced from a several-celled ovary, in which the cells have been obliterated, and all but one of the ovules have disappeared during growth. It is often enclosed in an involucre, called a *cupule* (Fig. 227), or it has bracts at the base.

Samara, or Key-fruit (example, the elm).—A dry, indehiscent fruit, growing single or in pairs, with a winged apex, or margin (Fig. 228).

Dehiscent Fruits.

Any dry, dehiscent fruit, whether simple or compound, may properly be called a pod.

Follicle.—A pod of a single carpel, with no apparent dorsal suture, and dehiscing by the ventral suture. You will seldom find an ovary consisting of but one follicle; but it is a common kind of carpel in multiple pistils. Observe the ripe ovary of colum-

bine or pæonia. Each carpel is a follicle, and you may find them slightly coherent at the base, as if forming a transition between the apocarpous and syncarpous pistil.

Legume.—A pod of a single carpel, with dorsal and ventral sutures and dehiscing by both or either, as the pea and bean pod. It assumes many different forms.

One of these, the Loment, is a sort of legume with transverse joints between the seeds, and falling to pieces at these joints (Fig. 229).

Another variety, the Silique, is a two-valved, slender pod, with a false dissepiment, from which the valves separate in dehiscence. It has two parietal placentæ (Fig. 230).

Fig. 229.

Fig. 230.

Fig. 231.

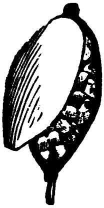
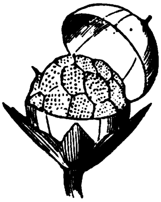


Fig. 232.



Silicle.—A short, broad silique (Fig. 231).

Pyxis.—A pod which dehisces by the falling off of a sort of lid (Fig. 232).

CAPSULE.—The pod of a compound pistil; the dry, dehiscent fruit of syncarpous pistils (Figs. 233 and 234). The pieces into which a capsule falls at dehiscence are called valves, the same as in one-carpelled fruit.

FIG. 233.

FIG. 234.

Those fruits that consist of achenia on a dry receptacle, as the sunflower, or on an enlarged, pulpy receptacle, as the strawberry, or those which consist of small drupes on a dry, spongy receptacle, crowded almost into one mass, as the blackberry, are *aggregate fruits*. They are sometimes called *etærio*.

Accessory, or anthocarpous fruits, are such as consist of other parts of the flower only apparently joined with the ovary.

MULTIPLE, COLLECTIVE, or CONFLUENT FRUITS, are formed by the union of many separate flowers into one mass (Figs. 235 and 236).

The sorosis is a kind of multiple fruit, to which

the pineapple (Fig. 235) belongs. The fig is a multiple fruit of the kind known as *syconus*, while *strobilus* is the name given to the multiple fruit of trees of the pine family.

FIG. 235.

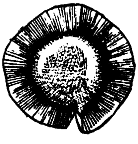
FIG. 236.

EXERCISE XXXIX.

The Seed.—Its Form and Surface.

The forms of seeds vary very much. They may be globular, ovoid, reniform, oblong, cylindrical, topshaped, angular, etc. Some seeds are small and fine, like sawdust; others are flattened and bordered, as seen in Fig. 237.

FIG. 237.



The surfaces of seeds may be smooth, striated, ribbed, furrowed, netted, and tubercular, as shown in the following figures:

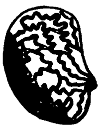
FIG. 238.

Smooth.

FIG. 239.

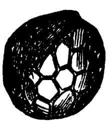
Striated.

FIG. 240.



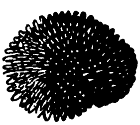
Ribbed.

FIG. 241.



Netted.

FIG. 242.



Tubercular.

FIG. 243.

Furrowed.

Seeds are said to be *definite* when few and constant in number; *indefinite* when numerous and variable.

Seeds are *solitary* when single in the ovary, or in a cell of the ovary.

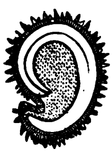
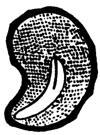
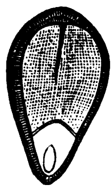
The albumen of seeds is the mass of tissue in which the embryo is embedded. It is said to be *mealy* when it may be readily broken down into a starchy powder; *oily*, when loaded with oil; *mucilaginous*, when tough, swelling up readily in water; and *horny*, when hard, and more or less elastic.

ALBUMINOUS SEEDS are those which have albumen.

EXALBUMINOUS SEEDS are those in which the body consists of the embryo alone.

The relations of embryo to albumen in various seeds are here shown. Your own observation, however, must have already supplied you with much information upon this subject.

FIG. 244. FIG. 245. FIG. 246. FIG. 247. FIG. 248.

EXERCISE XL.

Position of the Embryo in Seeds.

As the dissection of seeds is such an easy operation, you must be familiar with the different aspects of the embryo in many different seeds. You have seen it large and small, straight and curved, outside the albumen and embedded within it; sometimes with flat cotyledons, and sometimes with cotyledons folded or coiled in various ways and degrees. We are now to observe its relation to the parts of the seed.

In studying ovules, you found the hilum and the micropyle, and you may find the same parts in the seeds that were once ovules. The hilum of seeds is

usually obvious enough, and the micropyle may be easily found. You have only to soak the seed till its coats are distended with water, and, on squeezing, the micropyle, or orifice in the coats, is made apparent by the escape of water at that point. The place of the micropyle is important, because the radicle of the embryo always points toward it, and, in sprouting, issues through it, and the relation of the micropyle to the hilum determines the attitude of the embryo. Seeds are straight, half inverted, inverted, and curved, the same as ovules, and the same terms are used to express these facts in regard to them. In a straight or orthotropous seed (Fig. 249), the micropyle being at the apex, you find an inverted embryo, like Fig. 250. In this case the embryo is said to be *antitropal*, or reversed.

FIG. 249.

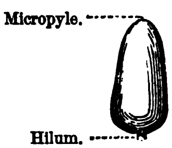


FIG. 250.

If the micropyle be turned to one side, as in Fig. 251, an amphitropous seed, the embryo, will be ob-

FIG. 251.

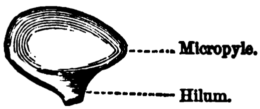


FIG. 252.

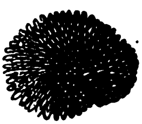
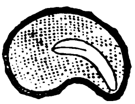


FIG. 253.

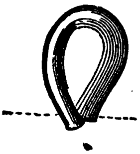


lique, as seen in Fig. 253. In this case the embryo is said to be *heterotropal.* Fig. 252 represents the seed which is shown in section in Fig. 253.

If the seed be inverted, or antitropous (Fig. 254), the embryo will be erect, as shown in Fig. 255. Here the embryo is said to be *orthotropal.*

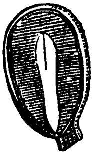
FIG. 254.

Hilum.



Micropyle.

FIG. 255.



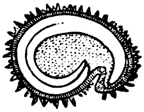
In Fig. 256, which represents a seed curved upon itself so as to bring the orifice next the hilum, or point of attachment (campylotropous seed), you may find the embryo presenting the appearance shown in Fig. 257.

FIG. 256.

Hilum.

Micropyle.

FIG. 257.



When the embryo is in the centre of the albumen (Fig. 255), it is said to be *axial;* and when not in the centre, it is said to be *excentric.*

Among the various modes of folding to which the embryo is subject, there are two which have been specially noticed and named, because they occur so uniformly in certain groups of plants. They are *cotyledons accumbent;* that is, with the radicle folded against their edges; and *cotyledons incumbent,* having the radicle folded against the back of one of them.

The following questions, forming a pistil-schedule, may now be used as a guide for pupils in describing this important organ of plants:

Form and position of stigma?
Form and position of style?
Kind of pistil?
Placentation?
Dehiscence?
Direction of ovules?
Kinds of ovules?
Fruit?
Seed?
Embryo?

Achenium (Gr., *a*, not; *chaino*, I open).
Capsule (Lat., *capsula*, a little chest).
Caryopsis (Gr., *kare*, a head; *opsis*, appearance).
Cremocarp (Gr., *kremao*, I hang; *karpos*, fruit).
Cypsela (Lat., a martin, or swallow).
Drupe (Lat., *drupæ*, unripe olives).
Epicarp (Gr., *epi*, upon; *karpos*, fruit).
Endocarp (Gr., *endon*, within).
Etærio (Gr., *etarios*, a companion).
Follicle (Lat., *folliculus*, a little bag).
Legume (Lat., *legumen*, pulse).
Loment (Lat., bean, meal).
Mesocarp (Gr., *mesos*, middle; *karpos*, fruit).
Pome (Lat., *pomum*, an apple).
Pyxis (Lat., a little box).
Silique (Lat., *siliqua*, a husk, or pod).
Sorosis (Gr., *soros*, a heap).
Strobilus (Lat., a fir-cone).
Syconus (Gr., *sukon*, a fig).

CHAPTER VI.

FLORAL SYMMETRY, PHYLLOTAXY, PREFOLIATION, CYMOSE INFLORESCENCE, ETC.

EXERCISE XLI.

Numerical Plan of the Flower.

When, in examining a flower, you count the parts of its calyx and corolla, the stamens and the carpels, and find that some particular number occurs again and again; and when, in case of deviation, you fre-

Fig. 258.

Fig. 259.

quently find multiples of it, the plan of the flower is said to be based upon this number. For instance, the plan of the flower represented in Fig. 258 is based on the number three. The plan of the flowers represented in Fig. 259 is based on the number four, and that of Fig. 260 upon the number five. In other words, in Fig. 258, three, or its multiple, six, is the constant number; in Fig. 259, four is the prevailing number; while in Fig. 260, it is five.

Fig. 260.

What numbers have occurred oftenest in your written descriptions of flowers? When you describe a flower, observe always what figures you use in numbering its parts, and decide what number the plan of the flower is based upon.

EXERCISE XLII.

Alternation of Parts in Flowers.

Figs. 262 and 263 represent the stamens and pistil of the flower shown in Fig. 261. Does this picture

FIG. 261.

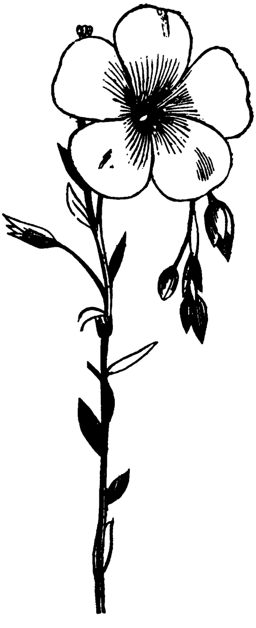


FIG. 262.

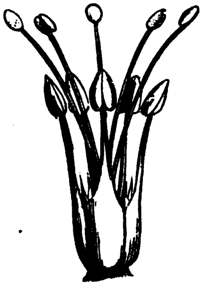


FIG. 263.

represent a perfect flower? Does it represent a complete flower? a regular flower? a symmetrical flower? Fig. 264 is a cross-section of this flower, given to illustrate the relation of the parts to each other. Observe that the petals alternate with the sepals; that is, they stand opposite to the openings, between the sepals. In the same way the stamens

FIG. 264.

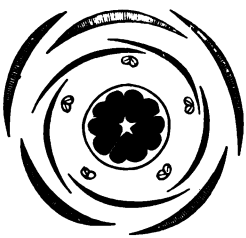
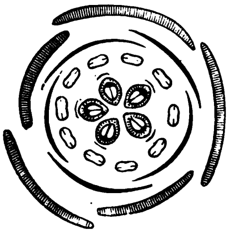


FIG. 265.

FIG. 266.

FIG. 267.



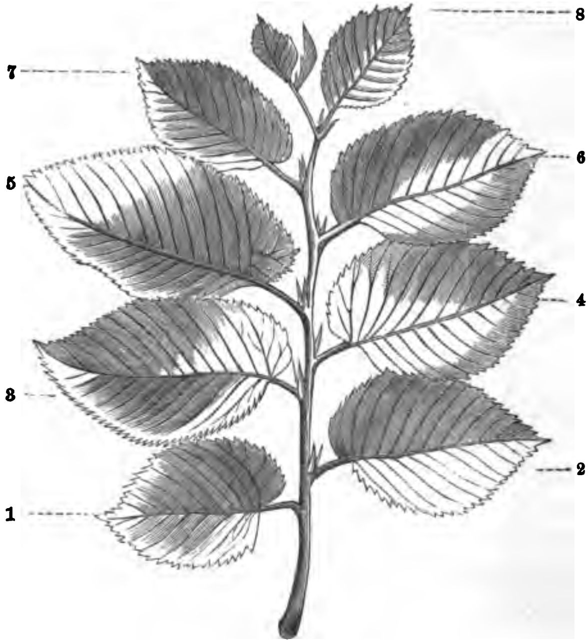
alternate with the petals, and the carpels with the stamens. This regular alternation of parts is spoken of as a symmetrical arrangement of the flower. Fig. 267 is the cross-section of Fig. 265, and Fig. 266 gives a vertical section of the same flower. Are its parts arranged symmetrically? that is, is the alternation perfect?

You see that flowers present symmetry of arrangement as well as symmetry of numbers, and it is important that you should observe them in this respect. Determine what parts of the flower you are studying alternate symmetrically, and where the symmetry fails. You will often find these observations valuable in classification.

EXERCISE XLIII.

Leaf Arrangement.—Phyllotaxis.

FIG. 268.



To study leaf arrangement, get straight leafy stems, or shoots, a foot or more in length, such as are shown in Figs. 268 and 269, from any vigorous tree, shrub, or herb. First separate the specimens having opposite and verticillate leaves from those with alternate leaves.

FIG. 269.

Observe that the successive pairs of leaves in opposite-leaved plants are placed at right angles to each

other, each leaf of the upper pair being placed over a space left by the lower pair. They are hence called *decussate* leaves. In the same way the whorls of leaves in verticillate-leaved stems are so placed that they alternate with each other.

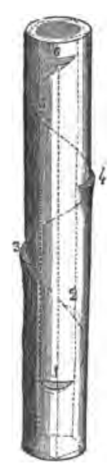
Observe the arrangement of leaves in the stems of grasses, and in stems with equitant leaves.

Put by themselves all the stems in which the leaves are neither decussate nor whorled.

Examine them, one after the other, thus: Take a small string, and, holding one end of it just below one of the lower leaves of your specimen, carry it up and around the stem (Fig. 270), so that it shall pass just

FIG. 270.

FIG. 271.



under each successive leaf. Proceed in this way till you reach a leaf standing directly over the one you started with. Your string now includes what is

called a leaf-cycle; that is, the distance in a spiral line around the stem, from one leaf to another placed exactly above it.

FIG. 272.

Holding the string in place, observe, first, how many times it has wound around the stem; and, secondly, how many leaves it passes on its way. If, in passing from the first leaf to the one directly over it, the string makes but one circuit around the stem, and the third leaf is over the first, so that the cycle includes but two leaves, the fourth leaf being over the second, and so on, you have an arrangement like that

seen in Fig. 268. The leaves in this example are seen to form two rows along the side of the stem, which are separated by half its diameter.

This is the distichous, two-ranked, or $\frac{1}{2}$ arrangement.

If, in passing from one leaf to another, directly above it, the string goes but once round the stem, and the fourth leaf is over the first, giving a cycle of three leaves, the arrangement is like that shown in Figs. 269 and 270. There are three perpendicular rows of leaves along the stem, separated from each other by $\frac{1}{3}$ its circumference.

This is the tri-stichous, three-ranked, or $\frac{1}{3}$ arrangement.

Again, the string may pass twice around the stem before it reaches the leaf placed just over the first, which, on counting, proves to be the sixth (Fig. 272). There are five longitudinal rows along the stem, separated from each other by $\frac{2}{5}$ its circumference.

This is the pentastichous, quincuncial, or $\frac{2}{5}$ arrangement.

Observe that the numerator in the foregoing fractions gives the number of times the string winds around the stem in completing a cycle, while the denominator gives the number of leaves in the cycle.

This fraction is sometimes called the angle of divergence of the leaves. In Fig. 268 the angle of divergence is $\frac{1}{2}$ the circumference of the stem; in Fig. 269 it is $\frac{1}{3}$, and in Fig. 271 it is $\frac{2}{5}$ its circumference.

In studying some of your specimens, the string may pass three times round the stem in its spiral course before you come to a leaf placed over the first, and this leaf may be the ninth in the upward succes-

sion, eight leaves being required to complete the cycle. Here you have eight perpendicular rows of leaves, with an angular divergence of $\frac{3}{8}$ the circumference of the stem; it is, therefore, called the $\frac{3}{8}$ arrangement.

In some plants the leaf-cycle includes five turns of the spiral and thirteen leaves, so that the fourteenth is placed over the first. This is the $\frac{5}{13}$ arrangement. There are also the $\frac{8}{21}$, the $\frac{13}{34}$ arrangements, and so on. But these more complex modes are only found where leaves grow in rosettes, as the houseleek, or in the case of crowded radical leaves, or in the scales of cones. In these cases the vertical rows are not distinguishable, and the order has to be made out by processes of reasoning rather than by simple observation.

There is a curious feature of the fractions expressing the angular divergence of leaves. Observe that any one of the fractions of the series is the sum of the two preceding simpler ones. For example, the angles of divergence in Figs. 268 and 269 are $\frac{1}{2}$ and $\frac{1}{3}$. Adding these numerators and these denominators, we have $\frac{2}{5}$, the pentastichous, or next more complex arrangement. By adding, in the same way, $\frac{1}{3}$ and $\frac{2}{5}$, we get $\frac{3}{8}$, while $\frac{2}{5}$ and $\frac{3}{8}$ give $\frac{5}{13}$, and so on.

The $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{2}{5}$ modes of arrangement are so definite and simple as to be easily discovered; but, it is not worth while, ordinarily, to continue the study of a specimen if it does not belong to one of these modes. A slight twisting of the stem, a considerable lengthening of internodes, or their absence altogether, renders observation difficult, and the decision uncertain. So, when commencing the study of leaf-arrangement,

take care to select the straightest and thriftiest stems for the purpose.

Examine the arrangement of bracts, and see if they follow the same order as leaves.

Observe whether the spirals take the same direction in branches as in the parent stem. When they do, they are called *homodromous;* but when they turn in opposite directions, they are said to be *heterodromous.*

Give the numbers of the leaves in each perpendicular series in your specimen showing the $\frac{1}{2}$ arrangement (Fig. 268).

In the $\frac{1}{3}$ arrangement, what leaf stands over the first? over the second? the third? fourth? fifth? Give the series of numbers that belong to the leaves of each row.

The name applied by botanists to these modes of leaf-arrangement is *phyllotaxis.*

EXERCISE XLIV.

Arrangement of Floral Leaves in the Bud.—Æstivation, or Præfloration.

In most common flowers, the floral circles, calyx, corolla, etc., appear quite distinct; but have you never observed cases in which it was doubtful where the calyx ended and the corolla began? or, where the corolla ended and the calyx began? or, even, where the bracts ended and the calyx began? Have you never seen petaloid sepals? that is, sepals with the

color and delicacy of petals? Have you not seen in the same flower some sepals that were green, and some changed more or less toward petals? or, the same sepal green without and petal-like within? Have you not seen the involucre made up of colored bracts, which gave it the aspect of a corolla? Have you not sometimes met with flowers in which you could see the gradual transition from petals to stamens? or flowers in which some of the stamens or carpels were changed to green foliage-leaves? Have you ever known of single flowers becoming double by cultivation, and of stamens and carpels replaced by petals? Did you ever happen to see a leafy shoot growing out from the centre of a flower, or of a flower-bud? All these appearances are common enough; and, if you have not seen them, you may easily do so by keeping your eyes about you.

It is from these singular aspects of plants, joined with the study of their development, that botanists have come to regard flowers as altered branches, and floral leaves as changed foliage-leaves. They speak of carpels as carpellary leaves, stamens as staminal leaves, petals as corolla-leaves, and the sepals as calyx-leaves.

If this be so, the laws of arrangement of floral leaves ought to agree with the phyllotaxy of foliage-leaves. Botanists say that it does so agree, and the place where it is best seen is in the flower-bud. The arrangement of floral leaves should also be studied, because it is important in helping to determine the affinities of plants.

To observe this arrangement, make an horizontal section of a bud just before it opens. Be careful to

make the section in the upper part of the bud, where the petals and sepals are most easily seen. Observe, with a magnifying-glass, the disposition of parts, and compare your examples with the modes of arrangement here pictured and named.

In VALVULAR præfloration there is no overlapping of parts. The edges of the sepals and petals just meet, and the flower is almost always regular (Fig. 273).

INDUPLICATE is a form of a valvate æstivation, in which the edges are turned slightly inward, or touch by their external face (Fig. 274).

FIG. 273.

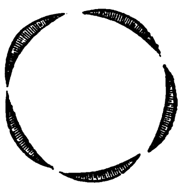
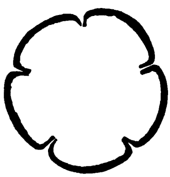


FIG. 274.



REDUPLICATE is a form of valvate æstivation, in which the edges turn slightly outward, or touch by their internal face (Fig. 275).

In the CONTORTED arrangement, each leaf overlaps its neighbor, and the parts seem twisted together (Fig. 276). It becomes CONVOLUTE when each sepal or petal wholly covers those within it.

FIG. 275.

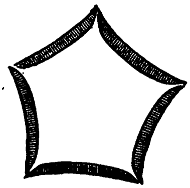


FIG. 276.

In IMBRICATE æstivation, the parts of a floral circle, usually five, are placed as seen in Fig. 277. The first leaf is external, the fifth internal, and the intermediate ones successively overlap each other.

The QUINCUNCIAL arrangement is seen in Fig. 278. There are two exterior leaves, two interior, and one intermediate.

FIG. 277.

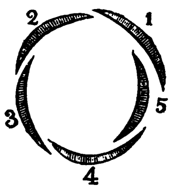
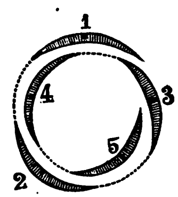


FIG. 278.



The VEXILLARY arrangement (Fig. 279) is a form of the quincuncial, where one of the petals, that ought to be internal, has, by rapid growth, become larger than the others, and external to them, so as to cover them in.

In the COCHLEAR arrangement, inequality of development has produced the order seen in Fig. 280.

We are reminded of the DECUSSATE arrangement of foliage-leaves by the position of the floral leaves shown in Fig. 281.

FIG. 279.

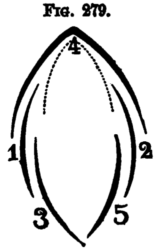


FIG. 280.

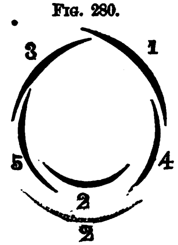


FIG. 281.

The SUPERVOLUTE arrangement is the name given to the folding of the gamosepalous calyx, or the gamopetalous corolla (Fig. 282). Observe whether the overlapping is from right to left, or from left to right, as you stand before the flower. Observe, also, whether the mode of arrangement is the same in the calyx and corolla.

FIG. 282.

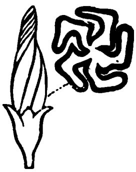


FIG. 283.

The plaiting of a gamopetalous corolla is shown in Fig. 283.

EXERCISE XLV.

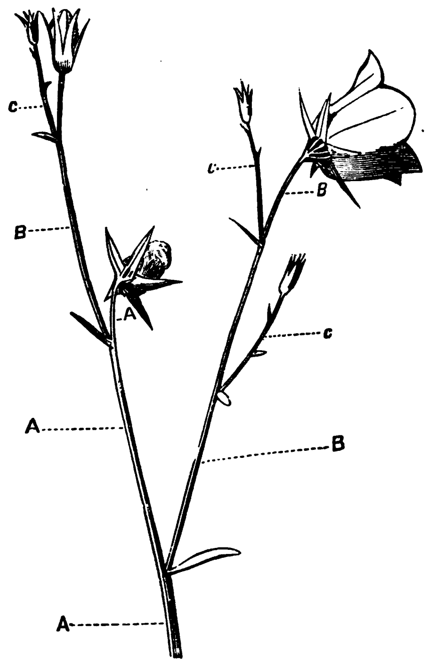
Cymose, or Definite Inflorescence.

In the "First Book" nothing was said about the varieties of definite, or cymose inflorescence, because it often requires much skill and patience to determine whether a particular panicle, corymb, raceme, or head, is definite or indefinite.

The buttercup, wild-columbine, rose, and cinquefoil, are common examples of cymose inflorescence among alternate-leaved plants, while Saint-John's-

wort, chickweed, sedum or live-forever, dog-wood, elder, hydrangea, are opposite-leaved examples. Get as many of these as you can, and begin the study with the inflorescence of an alternate-leaved plant. Compare it with Fig. 284. In this plant each shoot

FIG. 284.



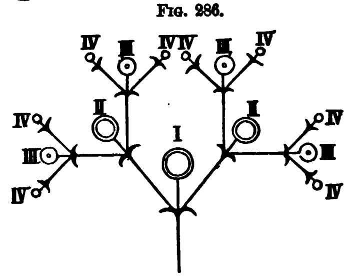
terminates in a flower, and the growth is continued by means of branches. In this figure the main, or primary stem (A, A), terminates with a flower which must, of course, be the oldest of the cluster. The branches (B, B, B) continue the growth, blossom, and

cease to lengthen. From these branches proceed others (C, C), and so on.

Such a loose, irregular, definite inflorescence is called a *cyme;* but, when the number of branches is greatly increased, and the peduncles acquire such lengths as to give a peculiar outline, the cluster receives a more special name. Fig. 285 represents the cymose inflorescence of an opposite-leaved plant. The main, or primary stem, terminates in a flower between two branches. These branches, or secondary stems, also terminate in flowers, each one of which is situated between branches of the third order, and so on. In this way is formed a *forked* or *dichotomous cyme.* If, in place of two, we have three branches, forming a sort of whorl around the primary stem, and each of these branches has another whorl of three tertiary branches, and so on, we get a trichotomous cyme. When the branching is carried forward, as seen in Fig. 286, the cyme becomes *globose.* When the central flower is suppressed, the process of development is not easily traced.

FIG. 285.

FIG. 286.



Suppose that, at each stage of the branching in Fig. 285, one of the divisions is regularly suppressed, as shown in Fig. 287, where the dotted lines take the place of the absent branches, the cyme is apparently changed into a one-sided raceme, and the flowers seem to expand in the same way as in the indefinite raceme. In opposite-leaved plants bearing this kind of inflorescence, the leaf or bract opposite the flower shows that the raceme is definite; but when, as in Fig. 288,

FIG. 287.

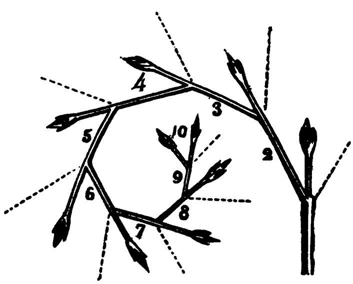
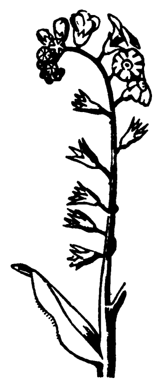


FIG 288.



there is no such bract, it is not easy to decide whether the cluster is definite or indefinite. However, the one-sided mode of branching gives the stem a coiled appearance, which is characteristic of the false or cymose raceme, and has led to the name *scorpioid* which is sometimes applied to it.

You may know a *cymose umbel* by observing that its oldest flowers are in the centre of the cluster

(Fig. 289), with buds, on short peduncles, surrounding them.

A Fascicle (Fig. 290) is a cymose cluster of nearly sessile flowers.

Fig. 289.

Fig. 290.

Fig. 291.

A GLOMERULE is a cymose cluster of sessile flowers in the axil of a leaf (Fig. 291).

What is known as compound inflorescence occurs when the flower-clusters of a plant develop in one way, and the plant itself develops in another way. For instance, in Fig. 291 each cluster is definite, or cymose, while the stem that bears them is indefinite. This state of things is often met with. Compare the development of the sunflower with that of catnip and horehound in this respect.

The indefinite mode of growth is sometimes spoken of as centrifugal, because the flowers open first at the circumference; while definite forms are said to be centrifugal, because here the flowers open at the centre first.

EXERCISE XLVI.

Duration of Floral Envelops.

The floral whorls are said to be CADUCOUS when they fall off at the opening of the flower. Examples, calyx of the poppy, corolla of the grapevine.

DECIDUOUS, when they fall before the fruit is formed.

PERSISTENT, when they remain till the fruit is matured, as is frequently the case with the calyx of inferior fruit.

MARCESCENT, when they persist in a dry and withered state.

EXERCISE XLVII.

Surfaces.

The surfaces of plants are said to be SILKY when the hairs are long, very fine, and pressed closely to the surface, so as to present a silky appearance.

ARACHNOID, when the hairs are very long, and loosely entangled, so as to resemble cobweb.

BEARDED, when the hairs are long, and placed in tufts.

DOWNY, or PUBESCENT, when the hairs form a short, soft stratum, which only partially covers the cuticle.

HAIRY, when the hairs are rather longer, and more rigid.

VILLOUS, very long, very soft, erect, and straight.

VELVETY, short, soft, very dense, but rather rigid, forming a surface like velvet.

Æstivation (Lat., *æstivus*, summer).
Arachnoid (Gr., *arachne*, a spider).
Cochlear (Lat., *cochlea*, a snail).
Convolute (Lat., *convolutus*, wrapped together).
Cyme (Lat., *cyma*, a sprout).
Decussate (Lat., *decussatus*, cut crossways).
Dichotomous (Gr., *dichotomos*, divided into two).
Distichous (Gr., *dis*, twice; *stichos*, a rank).
Heterodromous (Gr., *eteros*, another; *dromos*, course).
Homodromous (Gr., *omios*, similar).
Induplicate (Lat., *in*, in; *duplicatus*, doubled).
Marcessent (Lat., *marcesco*, I decoy).
Phylotaxis (Gr., *phullon*, a leaf; *taxis*, order).
Quincuncial (Lat., *quincunx*, an arrangement of five).
Supervolute (Lat., *super*, upon; *volutus*, rolled).
Vexillary (Lat., *vexillum*, a standard).
Villose (Lat., *villus*, wool).

CHAPTER VII.

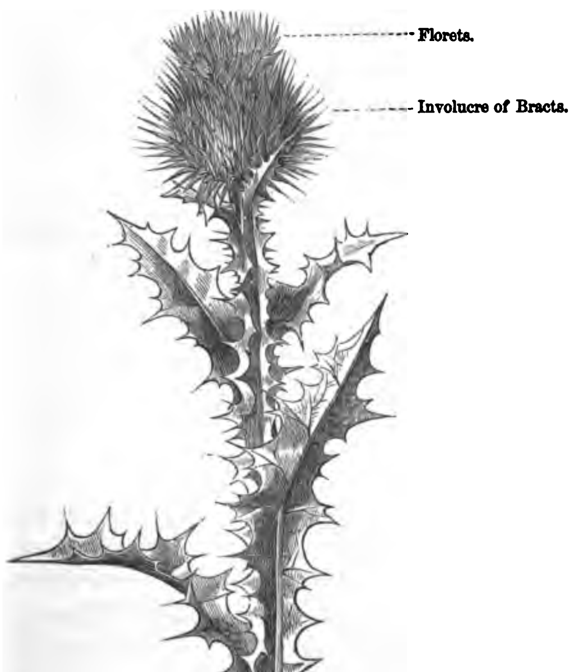
THE COMPOSITÆ.

EXERCISE XLVIII.

Parts of Flower-Heads.

To illustrate this chapter, gather all the plants you can find that have the inflorescence in a dense

FIG. 292.



head. The dandelion, thistle, aster, marigold, sunflower, daisy, dahlia, burdock, mayweed, bachelor's-button, boneset or thoroughwort, golden-rod, lettuce, saffron, cudweed or everlasting, wormwood, tansy, yarrow, feverfew, camomile, ragweed, tickseed, elecampane, are familiar examples of such plants. For your first observations select some flower-head in which the parts are well developed, as the marigold, thistle, or dandelion. Fig. 292 shows a thistle-head, with lines pointing to its principal divisions.

FIG. 293.

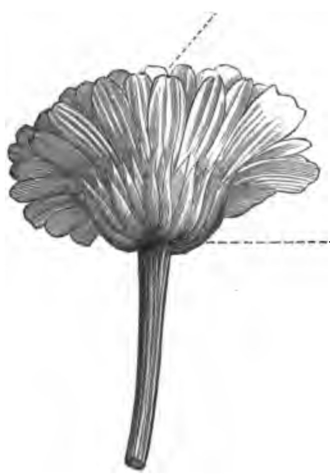


Fig. 293 represents a marigold, in which the same parts are shown. In Fig. 294 we look down upon the top of the flower-head, and observe that it presents unlikeness of aspect, which is still more plainly seen in the section (Fig. 295).

FIG. 294.

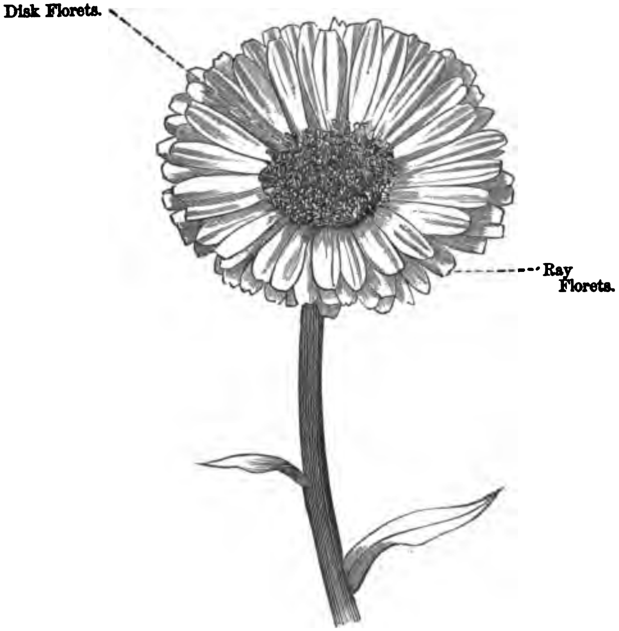
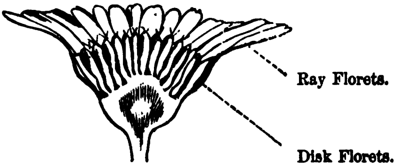


FIG. 295.



The parts pointed out in these pictures may be thus defined:

INVOLUCRE.—The outer green circle of a flower-head, often mistaken for a calyx.

SCALES.—The bracts forming the involucre of a flower-head.

FLORETS.—The flowers of a flower-head.

RAY FLORETS.—The outer petal-like florets of a flower-head.

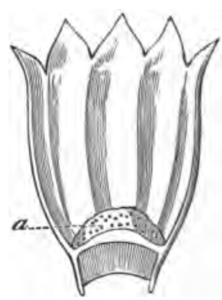
DISK FLORETS.—The inner florets of a flower-head.

Observe the bract at the base of the floret in Fig. 297. Observe the chaffy, bract-like bodies growing among the florets in Fig. 296. Examine your specimens, and see if, in any case, you find such things growing out of the receptacle among the florets.

FIG. 296.

FIG. 297.

FIG. 298.



These chaffy bodies are known as *paleæ*. When they are wanting, the receptacle is said to be naked. Separate the naked from the chaffy flower-heads of your collection.

In Fig. 298 you see the convex receptacle at *a*. Observe the different forms presented by the recep-

tacle in the last four figures. Strip away the florets from your flower-heads, and compare them in this respect. Are any conical in shape? Are any columnar? Are any pitted or honey-combed? In Fig. 298 is shown half the involucre of a marigold. Compare the involucres of your collection. They may be hemispherical, conical, inversely conical, squarrose, oblong, cup-shaped, etc. Their scales may be many or few; narrow or broad; in one or several rows; loosely or closely imbricate; chaffy, spinous, or soft; reflexed, colored, etc.

EXERCISE XLIX.

The Florets.

Let us now examine, with some care, the structure of florets. The flower-head here dissected is that of the marigold. If you cannot get this plant, take the sun-flower, or daisy, or dandelion and thistle, or any other flower-heads you happen to have. Of course, it is desirable, at the outset of study, to get the largest florets you can find.

Fig. 299.

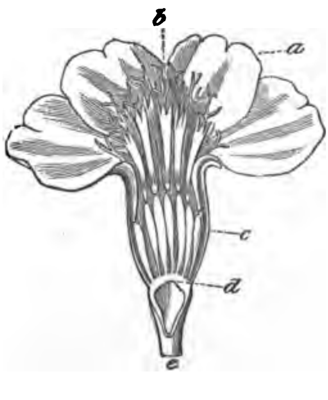


Fig. 299 represents a section of the marigold; *a*, the ray florets; *b*, the

disk florets; *c*, the involucre; *d*, the receptacle; and *e*, the peduncle.

Fig. 300 shows one of the ray florets, with its strap-shaped corolla, *d* the limb, and *c* the tube. At *e* is seen the forked stigma of the pistil; *a* is the ovary, and *b* the limb of the calyx. Compare this picture, or, what is better, a living example, with one of the florets of a dandelion, and carefully note the differences of structure they present.

Fig. 300.

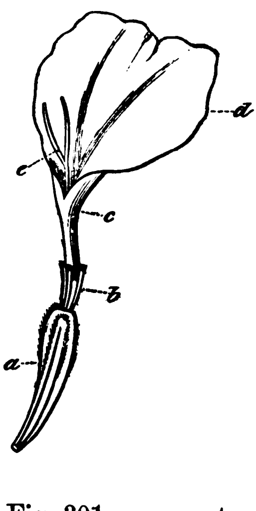


Fig. 301.

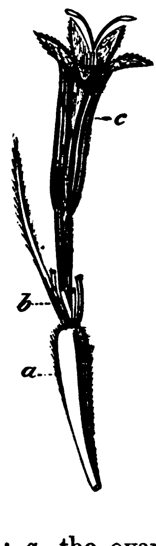


Fig. 301 represents a disk floret; *a*, the ovary; *b*, the limb of the calyx; and *c*, the tubular corolla. Compare this floret with those of the thistle, or any tubular florets in your collection.

In looking for the limb of the calyx in your specimens, you have found very various and peculiar ap-

pearances. This part of florets, from its singularity, has received the special name of *pappus*. In some, you observe, it does not exist at all, the adherent tube of the calyx forming an indistinguishable part of the ovary; in such cases the limb is said to be obsolete. Again, it is a mere rim, or border; sometimes it is cup-shaped, or bristly, or composed of teeth, scales, awns, or beards.

In the dandelion (Fig. 302) and the thistle it is silky. The reason given for this singular con-

FIG. 302.

FIG. 303.

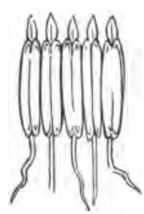
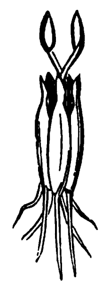


FIG. 304.



dition of the calyx-limb is, that it is starved and stunted while growing, by the constant pressure of the florets against each other. In the case of the dandelion, while the seed is maturing, the tube of the calyx is prolonged above the ovary into a kind of stalk, and the pappus is said to be *stipitate*.

But let us return to the florets. We have not yet examined their essential organs. Just below the stigma, in the disk floret (Fig. 301), is a cylindrical body, which, at first, you may not understand. Slit

it down, flatten it out, and examine it with your glass. Is not this cylinder composed of slender coherent anthers? Do you not see each anther with its filament, as shown in Fig. 303, which represents the tube seen in Fig. 304, thus laid open? The stamens of this floret are syngeneseous.

The following is a schedule of the ☿ and ♀ florets of the marigold:

SCHEDULE EIGHTH.

Organs.	No.	Cohesion.	Adhesion.
Calyx? *Sepals.*	5*	Gamosepalous. Limb of narrow scales.	Superior.
☿ Corolla? *Petals.*	5	Gamopetalous, tubular.	Epigynous.
☿ Stamens?	5	Syngeneseous.	Epigynous.
☿ Pistil? *Carpels.*	2	Syncarpous.	Inferior.
♀ Corolla? *Petals.*	5	Gamopetalous, strap-shaped.	Epigynous.
♀ Stamens?	0	0	0
♀ Pistil? *Carpels.*	2	Syncarpous.	Inferior.

* As the corolla is five-lobed, and there are five stamens, the florets seem to be five-merous, and we put the number of sepals as five.

The two carpels are inferred from the two-lobed stigma.

Study the florets of the dandelion. Is there more than one sort in the head? Select a well-developed floret, and describe it. Does your account agree with the following schedule:

SCHEDULE NINTH.

Organs.	No.	Cohesion.	Adhesion.
Calyx? *Sepals.*	5	Gamosepalous.	Superior.
Corolla? *Petals.*	5	Gamopetalous,	Epigynous.
Stamens?	5	Syngeneseous.	Epipetalous.
Pistil? *Carpels.*	2	Syncarpous.	Inferior.
Seeds?		Solitary, erect, exalbuminous.	

In the same way see how many sorts of florets you can find upon the thistle-head, and carefully describe whatever you find. Do the same for all the plants of this family that you have collected. When a flower-head has both disk and ray florets, note whether they are ♂, ♀, ☿, or neutral.

When you have done this, you will be able properly to apply the following terms to inflorescences of this order:

When all the florets of a head are *perfect*, it is said to be *homogamous*.

When part of the florets are *imperfect*, the head is said to be *heterogamous*.

Flower-heads are *discoid* when destitute of ray florets.

EXERCISE L.

Characters of the Compositæ.

Dandelions, daisies, dahlias, thistles, etc., we see, are composed of many florets, enclosed in a calyx-like involucre. Plants of this kind have, therefore, been named compositæ from the compound, or composite, nature of what, to the untaught, seems a single flower. They form one of the most numerous, and, at the same time, one of the most natural and perfect families in the vegetable kingdom. There are about nine thousand different species included in it. They are found in all countries and climates. About $\frac{1}{6}$ of the plants of North America, and $\frac{1}{2}$ of all tropical plants, belong to it; indeed, from $\frac{1}{8}$ to $\frac{1}{10}$ of all the plants in the world are of this order.

Now, why is this order said to be very natural? Why, for instance, is it a more natural group than the rose family? If examples of all these nine thousand species were brought together, they would be seen to have one conspicuous and many important characters in common. In every one of them the inflorescence is a dense head, enclosed in a more or less compact involucre. But, when you have collected all the members of the rose family, you do not see so many features common to all, nor any marked one which stamps them as similar. On the contrary, in all their

prominent characters, they are often widely unlike, and only experienced botanists can detect their affinities.

It must not be supposed, however, that all plants with flowers in a head belong to this family. The case is not quite so simple. Plants are not to be classified by a single character, you know. We must not forget our principle that characters of cohesion and adhesion in the flower are of the first importance in determining affinities.

Now, what are the characters of cohesion and adhesion in which the florets of all the plants named in Ex. XLVIII. agree? In the matter of cohesion, you

FIG. 306.

FIG. 307.

FIG. 308.

always found the calyx gamosepalous, the corolla gamopetalous, the stamens syngeneseous, and the forked style, of which Fig. 306 is a magnified view, seems to imply a syncarpous pistil, although the ovary is one-celled and one-ovuled.

In the matter of adhesion, you always found the calyx-tube adherent to the ovary (Fig. 308), forming the peculiar kind of achenium, known as a cypcela, and on further inspection you would find one erect exalbuminous seed (Fig. 307); and, if you were to examine the entire nine thousand species, you would find them all bearing the same characters.

But you need not discover all these characters before you decide that a given plant belongs to the composite order. If you find *syngeneseous stamens* in the florets of a dense *flower-head*, it settles the question. The coexistence of the two characters makes sure the inference that the plant has all the above-named characters, and also that it is more or less bitter.

Well, you have now the means of easily recognizing the members of this great family. They differ from all other plants, not in their inflorescence, for many other plants blossom in a head; not in having syngeneseous anthers, for in many other plants the anthers are coherent; but they differ from all other plants in possessing both these characters. This circumstance is, therefore, said to *characterize* the compositæ. Observe the distinction between that which characterizes an order and the characters of that order. The coexistence of the two characters—syngeneseous anthers and a flower-head—is sufficient to identify any plant of the order compositæ, or, what is the same thing, to characterize it; but all the other characters that invariably accompany these are the *characters of the order.*

Though all composite plants are alike in certain particulars, called their *ordinal characters*, they differ

much among themselves in other respects. Though they all have bitter properties, yet some are tonic, some acrid, and some narcotic. One group will have milky juice, another will be watery and aromatic, or mucilaginous, or gummy, or oily. In respect to the structure of flower-heads, you have already found the dandelion, with all its florets, perfect and ligulate; you found the thistle with perfect tubular florets, you found the marigold with ♀ ligulate disk florets, and ☿ tubular ray florets, the daisy with ♀ ray florets, and ♂ disk florets. Differences of this kind serve in arranging this vast family into sub-families, and these sub-families are again separated into smaller groups by still other characters. Differences in the involucre, and in the conditions of the inferior fruit, serve to separate them into what are called genera, and then the species of a genus are found to differ still further in the characters of leaf and stem, in size, color, etc.

In Order VIII. of Chart II., illustrating the Compositæ, the characters of the dandelion, thistle, marigold, bachelor's-button, and globe amaranth, are given; those of the dandelion and thistle are presented in full detail, and much enlarged.

CHAPTER VIII.

THE CRUCIFERÆ, OR CROSS-BEARERS.

EXERCISE LI.

Characters of the Cruciferæ.

THE plants of this order bear flowers with a cruciferous corolla. About sixteen hundred species have been discovered, and they are all wholesome. They grow in every zone and country, but chiefly in temperate regions. Both wild and cultivated species are common, and the characters by which they are known are few and obvious, so that you may easily make their acquaintance. Mustard, horse-radish, shepherd's-purse, turnip, cabbage, radish, pepper-grass, cress, and honesty, are familiar examples, which you must often have observed and studied; and I wonder how many of you can recollect certain characters peculiar to these plants. Procure them, and confirm, by direct observation, the following statements:

The flowers of this family of plants have four petals, so placed as to resemble a cross. They have six stamens, four long and two short (Fig. 114)—*tetradynamous stamens.* Their inflorescence is racemose, and *without bracts.* Any plant with these characters is a crucifer. These three characters are alone sufficient to *characterize* a plant as cruciferous; but they always accompany certain other traits of structure, which you will discover on glancing at the columns of the schedules you have made in describing them. In

each case there are four sepals and four petals. There is no cohesion in any of these flowers, unless you except the spuriously syncarpous pistil (Fig. 230). They are also without adhesion. I do not know how successful you may be in observing the embryo, but, with a good magnifying-glass, you should be able to see that the radicle is folded upon the cotyledons, sometimes against their edges, sometimes against the back of one, but always folded. Now, these invariable features are the *ordinal characters* of the cruciferæ. You may identify any one of the sixteen hundred known species by the three features first named, and, when you have done this, you may safely infer the existence of all the others. You are enabled to do this because botanists have carefully studied and analyzed these plants, and in every case, along with a cruciferous corolla, tetradynamous stamens, and bractless inflorescence, the other features have invariably been found.

I wish to say a word about the *importance* of the characters by which you determine whether a plant is or is not a crucifer. Some of you may think it strange that such features as the length of stamens and the absence of bracts should be named in describing an order of plants. These points of structure would not be looked upon as ordinal characters but for one circumstance, to be carefully borne in mind. It is their *constancy*, which here gives them value. They take rank from their *permanence*. Permanent or constant characters, no matter how trivial otherwise considered, are of high value in classification.

Order II. of Chart I. exhibits the characters of the cruciferæ as here described.

CHAPTER IX.

THE UMBELLIFERÆ.

EXERCISE LII.

Structure of its Flowers and Fruit.

THE plants of this family blossom in umbels. An umbel, with its pedicels all starting from one point, like the rays of an umbrella, is a feature of plants so striking that it has naturally given its name to the group that bears it. But, as you saw that a plant blossoming in a head did not necessarily belong to the compositæ, so you are now to find that all umbel-bearing plants are not, therefore, placed among umbelliferæ. It has been found that certain plants blossoming in umbels are alike in many other respects, and are at the same time unlike all other plants in the structure of their flowers, and particularly of their fruit. These umbelliferous plants constitute the family we are about to examine.

They are "natives chiefly of the northern parts of the northern hemisphere, inhabiting groves, thickets, plains, marshes, and waste places. They appear to be extremely rare in all tropical countries except at considerable elevations, where they gradually increase in number, as the other parts of the vegetation acquire an extra-tropical or mountain character."

At the outset let me warn you that this is an order of plants to be suspected. Though some of its species are excellent food, yet some, when eaten, are

deadly poisons, as hemlock, water-parsnip, and fool's-parsley. These poisonous species so strongly resemble esculent ones that only botanists can distinguish them, and many persons have made the fatal mistake of eating their roots. But the carrot, parsnip, parsley, celery, lovage, caraway, coriander, etc., are common cultivated species of this order, and none of the species are poison to the touch.

In your rambles you will be likely to find a large, coarse-looking, hairy or woolly, strong-scented plant, three or four feet high, which grows in moist, cultivated grounds, from Pennsylvania to Labrador, and west to Oregon. It has a thick, furrowed stem, ternate leaves, with large, channelled, clasping petioles, and blossoms in June, bearing huge umbels, often a

FIG. 309.

foot broad. It is a species of cow-parsnip, sometimes called masterwort. Its flowers have white, deeply-heart-shaped petals. As its parts are comparatively large, the flower of this plant is here chosen to exhibit the peculiarities of the order. In Fig. 309 it

is given in section, and here follows its schedule-description.

SCHEDULE TENTH.

Organs.	No.	Cohesion.	Adhesion.
Calyx? *Sepals.*	5	Gamosepalous.	Superior.
Corolla? *Petals.*	5	Polypetalous.	Epigynous.
Stamens?	5	Pentandrous.	Epigynous.
Pistil? *Carpels.*	2	Syncarpous.	Inferior.
Seeds?		One in each carpel—pendulous, albuminous.	

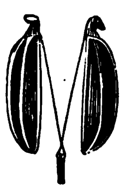
Now look at an ovary that has attained its full size, and lost its petals and stamens. It has turned brown, the furrows on its sides are deepened, and it separates into two halves, commonly called seeds (caraway-seed, for example). This ovary requires close study. In Fig. 310 you see its two carpels suspended in a peculiar manner. You may see in your specimen this slender, forked *carpophore.*

The fruit of the umbelliferæ consists of two achenia, called a *cremocarp,* and each achenium, or carpel, is called a *mericarp.* The inner faces of the carpels, which are in contact before ripening, are called the *commissure.*

Fig. 311 is a magnified view of the back of a

mericarp. Five ridges are seen passing from bottom to top of each mericarp, and often four intermediate or secondary ones, which may be, some, none, or all of them, winged. In the substance of the thin pericarp are little bags of colored oil, called *vittæ*, that give aromatic and stimulating properties to all the plants of this family. Four of these bags are seen in Fig. 311, in the intervals of the ribs. In the

FIG. 310.

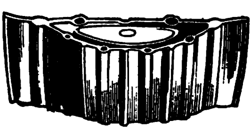


Cremocarp of two Carpels, each of which is a Mericarp.

FIG. 311.

Mericarp.

FIG. 312.



Cross-section of a Mericarp.

cross-section of a mericarp (Fig. 312) the little mouths of the four oil-bags of the back are seen, along with two others, in the face of the commissure. If you have difficulty in finding these oil-bags, cut the carpel across, as shown in Fig. 312, and look down upon it with your glass, and perhaps their cut ends will be visible to you. A thin section, moistened and seen under a microscope, reveals them very distinctly.

Collect all the plants you can find with this kind of inflorescence, and examine their flowers and fruit. In most cases you will need your glass and much patience in doing this; but, if you cannot discover

all the minute details of structure, you can, at least, tell whether the fruit of the plant is like that of the cow-parsnip or not.

EXERCISE LIII.

Classification of Umbel-bearing Plants.

If you verified the observations made in Ex. LII., you will understand the following description of the order Umbelliferæ:

CALYX, superior; LIMB, obsolete, or entire, or a five-toothed border. PETALS, five, mostly with the point inflexed, and, along with the five STAMENS, inserted on the outside of a fleshy, epigynous disk at the base of the two styles. FRUIT, consisting of two carpels, called *mericarps*, cohering by their faces, the commissure separating when ripe, and suspended from the summit by a prolongation of the receptacle, called a *carpophore;* each carpel is marked by five primary ribs, and a variable number of intermediate or secondary ones, between which are found oil-tubes, called *vittæ*, filled with aromatic oil. SEEDS, solitary, anatropous, with minute embryo in horny albumen.

HERBACEOUS plants, with hollow, furrowed stems. LEAVES, alternate, mostly compound, usually sheathing at the base (Fig. 313). FLOWERS, in umbels, usually compound, often with involucre and involucels (Fig. 314).

Some of the plants of this family are innocent and aromatic, others very poisonous.

So, you see, we have here a family of fifteen hundred species, all blossoming in umbels, and named

FIG. 313.

from this circumstance, and yet distinguished from the rest of the vegetable kingdom by quite other

FIG. 314.

characters than the inflorescence. If your notion of the order were founded on its name, or upon the *general aspect* of a few familiar species known to be-

long to it, you would most likely pronounce an elder-bush an umbelliferous plant. "You would find a large umbel, a small umbel, little, white blossoms, an inferior ovary, and five stamens. Yes, it must be an umbelliferous plant. But look again: suppose you take a flower. In the first place, instead of five distinct petals, you find a corolla, with five divisions, it is true, but, nevertheless, with all five joined into one piece; now, umbelliferous plants are not so constructed. Here, indeed, are five stamens, but you see no styles; you see three stigmas more often than two, and three grains more often than two; but umbelliferous plants have never either more or less than two stigmas, nor more or less than two grains to each flower. Besides, the fruit of the elder is a juicy berry, while that of umbelliferous plants is dry and hard. The elder, therefore, is not an umbelliferous plant. If you now go back a little, and look more attentively at the way the flowers are disposed, you will also find their arrangement only in appearance like that of umbelliferous plants. The first rays, instead of setting off exactly from the same centre, arise, some a little higher and some a little lower; the little rays originate with still less regularity; there is nothing like the invariable order you find in umbelliferous plants. In fact, the arrangement of the flowers of the elder is a *cyme*, and not an umbel."

But you need not search for all the characters given in the foregoing description in settling the question whether a plant is or is not umbelliferous. If it bears flowers in umbels, and produces inferior fruit, that when ripe separates into two seed-like

bodies, it is an umbelliferous plant. These simple features give precision and distinctness to the order, so that the study of minute characters is only needed in separating this large group into lesser groups with a still greater number of like characters and properties. The number and development of ribs, the presence or absence of vittæ, the form of albumen, etc., are used for this purpose. Hence, although a beginner readily separates the plants of this order from all others, he finds it difficult to tell one genus from another, and, till he acquires skill in observation and has some experience with this sort of plants, he is quite safe in looking upon all of them with suspicion.

But, if the pupil desires to carry his discriminations further, and to trace out the characters of genera and species contained within the order, there is no objection to his doing so, but he will require the aid of other works for the purpose. Complete classification is the final object of botany, and the present course of study is designed as an introduction to it. If, however, any students wish to do something with it as they go along, they will find some hints that may be useful in the last exercise of the volume.

In Order VI., of Chart II., the structure of umbelliferous plants is shown in detail. Enlarged sections of the fruit, with all its peculiarities of structure, are represented in such a way as to reveal the parts with great distinctness.

CHAPTER X.

THE LABIATÆ.

EXERCISE LIV.

Characters of the Labiatæ.

CHILDREN who live in or visit the country, and those familiar with market-places, know what mints are, and can easily get peppermint, spearmint, catnip, sage, pennyroyal, thyme, balm, and such like plants, to illustrate this exercise. Compare your specimens with the following description:

Herbs, with square stems and opposite aromatic leaves; flowers, with a more or less two-lipped corolla, didynamous or diandrous stamens usually with diverging anthers; ovary, deeply four-lobed, on a fleshy disk, four-celled, each cell with one erect ovule forming in fruit four little seed-like nutlets or achenia, around the base of the single style, in the bottom of the persistent calyx. Seeds with little albumen; cotyledons flat. Stamens inserted on the tube of the corolla. Stigma, forked. Flowers, axillary, chiefly in cymose clusters, that are sometimes gathered into spikes or racemes. Leaves, usually dotted with glands, containing a pungent, fragrant, volatile oil.

Whenever you find a plant that answers to this description, it belongs to the order Labiatæ. The group is named from the two-lipped corolla of its flowers, but you cannot know one of these plants by

this circumstance alone. There are many plants with labiate flowers that do not belong here. There are many plants with square stems, opposite leaves, and labiate flowers, that still do not belong in this order. Nor do you find in this list of characters any that may not be found elsewhere, as you do in the case of the fruit of Umbelliferæ, for instance. Is it, then, necessary, in every case, to make an extended and minute examination of plants suspected of being in this order before deciding that they really are so? We can best answer this question by carefully observing certain plants. First get a specimen of verbena, a widely-cultivated plant belonging to the family Verbenaceæ, and compare it with any of the labiate plants named in the beginning of this exercise, thus:

The Verbenaceæ are herbs or shrubs with opposite leaves.	The Labiatæ are chiefly herbs, with square stems, opposite, aromatic leaves.
More or less two-lipped or irregular corolla.	More or less two-lipped corolla.
Didynamous stamens.	Didynamous or diandrous stamens.
Two to four celled fruit, dry, or drupaceous, usually splitting, when ripe, into as many one-seeded, indehiscent nutlets.	A deeply four-lobed ovary, which forms in fruit four little seed-like nutlets or achenia surrounding the base of the single style in the bottom of the persistent calyx; each nutlet filled with a single erect seed.
Seeds, with little or no albumen; the radicle of the straight embryo pointing to the base of the fruit.	Albumen, mostly none; embryo, straight; radicle, at the base of the fruit.

The affinities of these orders are so strong that, at first, one almost wonders why botanists regard them as distinct. But we remember that the characters by which they differ, though not conspicuous, are yet very important, being characters of the essential organs and the fruit. The deeply-lobed ovary, with the style growing out from its base, and surrounded in fruit by the four nutlets, distinctly separates the two groups. But does this structure of the ovary distinguish the Labiatæ from all other plants? Let us see.

There is a family of rough, hairy herbs, known as borages, with flowers in cymose clusters, unrolling as they expand, as described (page 135), which it will be well to study with reference to this point. One of its species, the forget-me-not, is a common, widely-diffused plant of this order, which you may get, and compare with the following description:

The Boraginaceæ are chiefly rough, hairy herbs, with (not aromatic) alternate, entire leaves.	The Labiatæ are chiefly herbs, with square stems, and opposite, aromatic leaves.
Symmetrical flowers, with five-parted calyx, and regular five-lobed corolla.	More or less two-lipped corolla.
Five stamens inserted on the corolla tube.	Didynamous or diandrous stamens.
Ovary, deeply four-lobed, the lobes surrounding the base of the style, and forming in fruit four seed-like nutlets, each with a single seed.	Ovary, deeply four-lobed, forming in fruit four seed-like nutlets around the base of the single style, in the bottom of the persistent calyx, each filled with a single erect seed.
Albumen, none; cotyledons, plano-convex; radicle, pointing to the apex of the fruit.	Albumen, mostly none; embryo, straight; radicle, at the base of the fruit.

Here, then, is an order of plants, the Boraginaceæ, which is very different from the Labiatæ, except in the characters of the ovary, and in these characters it is almost identical with that order. You have in this instance an example of the puzzling relationships encountered in classification. The verbenas cannot be grouped with the labiates, because, though wonderfully like them in many other respects, they are so unlike in the characters of the pistil; the borages, though agreeing essentially with the Labiatæ in the characters of the pistil, cannot be classed with them, because of their differences in so many other respects.

At any rate, you now see that the structure of the ovary is not characteristic of the Labiatæ. To identify the members of this group, we have to bear in mind several characters, which you are prepared to do if you have examined and compared the plants named above. When you find a plant with a two-lipped corolla, square stem, and opposite leaves, joined with a deeply-lobed ovary and basic style, you need not hesitate to place it among Labiatæ.

You have now examined a good many species of plants belonging to four different natural families—the Compositæ, the Cruciferæ, the Umbelliferæ, and the Labiatæ. Can you tell whether their leaves are parallel-veined or net-veined? Have you ever seen a parallel-veined cruciferous plant? Have composite plants, as far as you know, parallel-veined or net-veined leaves? Try to find whether the leaves in the plants of these orders are alike in their venation.

Order XII., of Chart III., exhibits the characters of the Labiatæ.

CHAPTER XI.

THE CONIFERÆ.

EXERCISE LV.

Characters of the Coniferæ.

There is still another large group of widely-distributed plants that must be specially described. When we speak of evergreens, everybody knows what we mean, and thinks of pines, balsams, hemlocks, spruces, cedars, junipers, arbor-vitæs, or whatever species are most familiar. When we speak of cone-bearing trees or shrubs, it is not quite the same group of plants that is thought of, for, although everybody knows what cones are, yet untaught and unobservant people would hardly think of a juniper-berry as in any way allied to a cone. But, although cone-bearing trees are everywhere to be found, and universally known, yet very few people can tell when they flower, what sort of flowers they bear, or what a cone really is; and yet their structure and habits in respect to flowering and fruiting are even more remarkable than their general appearance. They are monœcious or diœcious, and blossom in spring. Their flowers are in clusters, usually aments, sometimes in the axils of the leaves, and sometimes at the extremity of the branches. The fruit is two years in ripening, so that the full-grown cones, seen upon them in summer, were blossoms the year before.

To study their flowers, you must begin in the

spring, and look carefully for the fertile and sterile aments, which will usually be found on different branches of the same tree. And, while you are searching for their flowers, observe also their remarkable foliage. Fig. 315 shows a fascicle of needle leaves from the pine. Observe the number of leaves in each fascicle of the specimen you are studying, for the species vary in this respect. Fig. 316 represents the scale-shaped leaves of arbor-vitæ. In evergreens of this sort observe the difference between the foliage on the older and newer parts of the plant. In diœcious species, observe whether the foli-

FIG. 315.

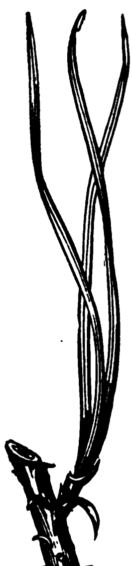


FIG. 316.

age is of the same kind on both ♂ and ♀ plants. When you find awl-shaped leaves upon a young branch, observe them from time to time, and note their gradual passage into scale-shaped, imbricate leaves. Do evergreens shed their foliage? If so,

when? and how long does the foliage last?* Can you find young foliage upon old branches?

In the pine the inflorescence of the sterile flowers is a kind of compound spike (Fig. 317). One of the spikelets much magnified is shown in Fig. 318. Each flower of this spikelet consists of a single stamen

FIG. 317.

only, and this stamen has a most peculiar structure. Its filament is so short as to be scarcely discernible. It is really a spikelet of anthers, and their connective. Remove a stamen, and examine its inner face.

* To find whether evergreens shed their foliage, you have only to watch the ground beneath them for fallen leaves. If you find that their foliage does fall, and wish to learn by observation how long it lasts, notice whether the twigs of the present year keep their foliage all through the coming winter. If they do, observe them again next summer, and if it is still retained, watch them the third season, and so on.

Compare it with Fig. 319, which is a ♂ flower of the pine. Here you see two anther-cells dehiscing vertically, and Fig. 320 represents a grain of the

FIG. 318.

FIG. 319.

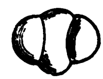


FIG. 320.

compound pollen they bear. Seen on the outside, this stamen appears to be all connective. This connective, or scale, as it is usually called, varies in form in different species of evergreens; but these of the ♂ catkins of the pine are enough like all the others to guide you in searching for and studying them. When they have shed their pollen, they wither and disappear.

The ♀, or fertile flowers, are also clustered, and appear at the same time as the ♂ ones, sometimes on the same, and sometimes on different branches. It is this ♀ catkin that, in a couple of years, develops into the fruit we call a cone. Fig. 321 represents it when in flower. The fertile flowers are very simple in structure, each one consisting of an open carpellary leaf, or scale. Hitherto you have always found seeds in seed-vessels, but here you will find them

borne upon one side of a scale, and hence the Coniferæ are said to be *naked-seeded.* Get one of these

FIG. 321.

♀ catkins, and detach from it a single flower. Compare it with Fig. 322. Observe the ovules upon its

FIG. 322.

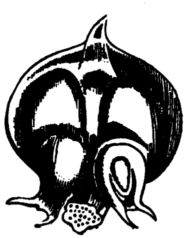


FIG. 323.

inner surface. These vary in number and position with the species examined. In this specimen of the pine we have two inverted ovules, which, in time, become seeds. Fig. 323 represents a scale from the same kind of catkin after it has become woody, and the seeds have ripened. The left side of this scale shows the cavity from which one winged seed has fallen, while on the other side a seed still remains. You may easily find these seeds in mature cones by breaking them across, or, what is better, by putting them in a dry place for a day or two, when the scales will cleave away and so reveal the seeds within.

In some evergreens, as arbor-vitæ and white cedar, when you examine the small terminal catkins, you will find the ♂ ones composed of several scales or flowers, each scale bearing two to four anther-cells on the lower margin (Fig. 324), while the globular ♀

FIG. 324.

FIG. 325.

catkins consist of four rows of scales, each scale or flower bearing one or several erect, bottle-shaped ovules at the base (Fig. 325). The developed cone of the white cedar is scarcely larger than a pea, with scales firmly closed, but opening at maturity.

The juniper or red-cedar, common on dry, sterile, rocky hills, both northward and southward, blossoms

in April. The various species are mostly diœcious, and the catkins are very small. Observed only when in fruit, you would scarcely regard the juniper as a coniferous plant, but the ♀ catkin, when in flower, is seen to consist of from three to six scales, bearing a variable number of ovules precisely in the same manner as the pine. But, in ripening, these scales grow together, turn purple, and form a berry-like fruit as

FIG. 326.

FIG. 327.

FIG. 328.

large as a pea. Fig. 326 represents one of these berries with its scaly bracts underneath, while Fig. 327 shows one of its enlarged bony seeds. The berries ripen the second year from the flower.

The ground-hemlock is another coniferous plant with a berry-like fruit. Its ♀ flower is more simple than those we have been examining, for it consists of a single ovule, without even an accompanying scale. This straggling bush, two or three feet high, is found in shady places, along streams, on thin, rocky soils, from Canada to Pennsylvania and Kentucky, and south along the Alleghanies. Its linear leaves are nearly an inch in length, in two opposite rows, along the branches. It blossoms in April. Fig. 328 repre-

sents its axillary ♂ inflorescence, consisting of six scale-like connectives, bearing the anther-cells on their inner faces. Fig. 329 represents its solitary fertile flower. You see it is a single, erect, sessile ovule, surrounded by scaly bracts. At its base is a cup-shaped disk, that becomes pulpy, red, and berry-like, as the ovule ripens and turns black. Fig. 330 represents a vertical section of this fruit.

Fig. 329.

Fig. 330.

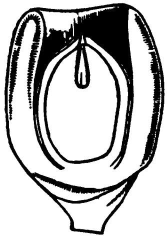


Fig. 331.

The embryo of a coniferous seed is shown in Fig. 331. It is said to be *polycotyledonous.*

The lower half of Chart IV. is devoted to the Coniferæ. Examples of the leading genera of this order are given, showing the foliage, fruit, and seed, the latter much magnified, and all colored from Nature.

CHAPTER XII.

THE ORCHIDACEÆ.

EXERCISE LVI.

Characters of the Orchidaceæ.

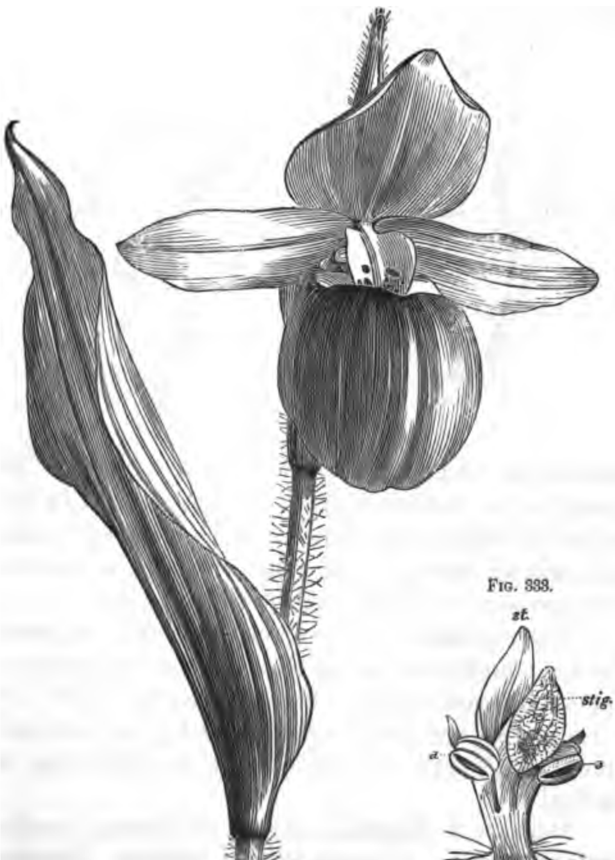
THERE is a widely-distributed and well-known plant, with showy flowers, blossoming in early summer, and called the lady's slipper, or sometimes the moccasin-flower (Fig. 332). It is an orchid; and, though unlike other orchids in some respects, it has the chief traits of the order to which it belongs.

Provide yourself with some of these plants, and compare them with the following description: Herbs with parallel-veined leaves and irregular flowers. Perianth of six parts in two sets; the three outer ones nearly alike, and petaloid in structure and appearance; the three inner ones unlike. One of these, differing much in shape and direction from the others, is called the *lip*. In Fig. 332 the lip is the sac or slipper, which gives the plant its common name. The lip varies much in different orchids, but in all its appearance is singular and striking. It is seen spurred and lobed, and assumes many fantastic forms.

Examine, now, the stamens and pistil of your flower. Lift up the little, drooping organ opposite the lip, and compare the structure beneath with Fig. 333. You have here the stamens and pistil consolidated into one organ, and known as the *column*. The

fertile anthers are shown at *a*, *a*, while a sterile stamen back of the stigma is marked *st.* The stigma is marked *stig.* The fertile anthers are sessile upon the style. In most orchids there is but one anther, which

FIG. 332.



is fertile, and placed behind the stigma, in the position of the sterile stamen of the lady's-slipper. Examine the pollen. Instead of being dry and powdery, you find it pulpy-granular. In many orchids it coheres into coarse grains, held together in one mass by cobwebby tissue, and known as *pollinia* (Fig. 334). You find just such pollen masses, or pollinia, in the gy-

FIG. 334.

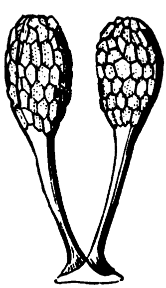
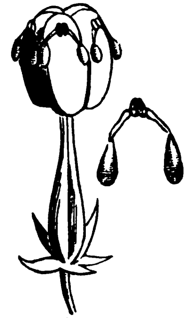


FIG. 335.



nandrous stamens of the milk-weed (Fig. 335). The ovary of the lady's-slipper is inferior, forming in fruit a one-celled pod, with innumerable minute seeds borne on parietal placentæ. In some orchids you find it so twisted as to alter the position of the petals.

The characters of the Orchidaceæ will be better understood by comparing them with other groups of parallel-leaved plants. Provide yourself with lilies of any sort, and specimens of blue-flag, or flower-de-luce. Compare your lilies with the following description:

Herbs with simple, sheathing or clasping, parallel-veined leaves. *Flowers* regular, perfect. Perianth

of six parts in two circles of similar color and form. *Stamens* six, inserted on the leaves of the perianth; anthers introrse. Ovary free, three-celled, with numerous ovules on axile placentas; the styles united into one.

What number have you found prevailing in the lilies you have examined? What number occurred oftenest in describing the Compositæ? The Labiatæ? The Umbelliferæ? The Cruciferæ? Point out the affinities of the lady's-slipper and the lily.

Compare flower-de-luce, or blue-flag, with the following description:

Herbs with parallel-veined, equitant, two-ranked leaves and perfect flowers. Tube of the perianth coherent with the three-celled ovary; limb petal-like and six-parted; convolute in the bud in two sets. *Stamens* three, monadelphous or distinct, with extrorse anthers. Pod three-celled, locolucidal, many-seeded.

What affinities can you point out between the flower-de-luce and lily? between the lady's-slipper and flower-de-luce? In what respect are these three plants alike?

The nature of orchids will be further explained in Course Second.

On Chart V. several orders of parallel-leaved plants are given, and their characters are so magnified that they may be easily seen and compared.

CHAPTER XIII.

THE GRAMINEÆ.

EXERCISE LVII.

Characters of the Gramineæ.

There is a large group of plants blossoming in peculiar-looking spikes, heads, and panicles, the flowers of which are furnished with green or brown scales, called *glumes*, whence the entire group is known as the Glumaceæ. They constitute a twelfth part of the described species of flowering plants, and at least nine-tenths of the individuals composing the vegetation of the world. They grow everywhere. All grasses and all the cultivated crops of grain belong among them, besides many other plants not so important to man. They have true flowers, but no calyx or corolla. The Glumaceæ are divided into two groups; one group—the sedges—having solid stems, while the other—the grasses—has hollow stems. The flowers of both these groups have a special structure, which your previous study will not enable you to understand.

From this large class we will select examples that belong to the family of grasses or Gramineæ, the members of which have hollow stems, and the sheaths of their ligulate leaves are spit in front.

Gather specimens of wheat, if possible, in blos-

soming-time, when the stamens are to be seen (Fig. 336). Along the rachis are rows of peculiar-looking bundles. The number of these rows varies in different kinds of wheat. Break the spike at about the middle, and take off a bundle from the top of the lower half. Observe whether it is attached by its side or its end, and whether any of its scales adhere to the rachis either wholly or in part.

FIG. 336.

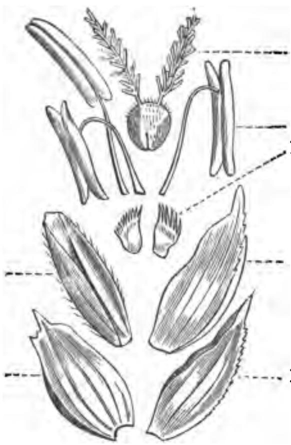
FIG. 337.

Remove the first two of these scales: there is no trace of either pistil or stamens within them. They are quite empty. What do you find next? Are there not two or three separate flowers forming a sort of spikelet within these two outer scales (Fig. 337)? Examine one of them.

In Fig. 338 a single flower is shown, with the two glumes found at the base of the spikelet, and called the *lower* and *upper glumes*. What remain are the parts of a single flower. Beginning

with the outermost of these at the right, you see a scale called the *outer palet.* Does the outer palet,

FIG. 338.



in the specimen you are studying, terminate in a bristle?

FIG. 339.

At the right you see a peculiar scale, folded at the sides, and called a *palet.* Then come the scales. Look carefully at your flower for these minute bodies, which are thought to be a sort of perianth, the outer and inner scales being of the nature of bracts. We next come upon the stamens, with their versatile anthers, and the pistil, with its plumose stigmas—the unmistakable flower. The peculiar features of this inflorescence, then, are—

Glumes.—Scales of the spikelet, and exterior scales of the flower.

Palets.—Chaffy, inner scales of the flower.

Awn.—The beard or bristle of a scale.

Squamula.—One of the minute scales at the base of the ovary of grasses.

The following questions, which form a schedule for this group of plants, are answered as if asked concerning Figs. 336 and 338:

Inflorescence?	Spike.
Glumes?	2.
Outer palet?	1.
Inner palet?	1.
Lodicules?	2.
Stamens?	3.
Styles?	2.

Answer these questions in regard to the heads of barley and rye. Compare the culm* and leaves of these plants with those of wheat.

Compare a plant of Indian-corn, when in blossom, with the following description: ♂ flowers in a terminal panicle of racemes known as the *tassel*; spikelets two-flowered; glumes herbaceous, palets membranous; anthers three, linear. ♀ flowers in an axillary spike, partially imbedded in the rachis, known as the *cob*, the bracts forming its spathe being the *husks*; lower flower of each spikelet consisting of two palets, abortive; glume broad, thick, membranous, obtuse; styles, very long, filiform, exserted and pendulous,

* *Culm:* a straw; the stem of grasses and sedges.

forming the *silk;* kernels in eight, ten, twelve, or some even number of rows.

Gather a plant of the oat in blossoming-time, and compare it with Figs. 340 and 341. Remember that the outer glumes belong to the spikelet, and not to the flower. Look out for sterile flowers below or above the perfect ones.

FIG. 340.

Compare the culm, leaves, and stipules of the oat with those of wheat, rye, and barley.

Fig. 341.

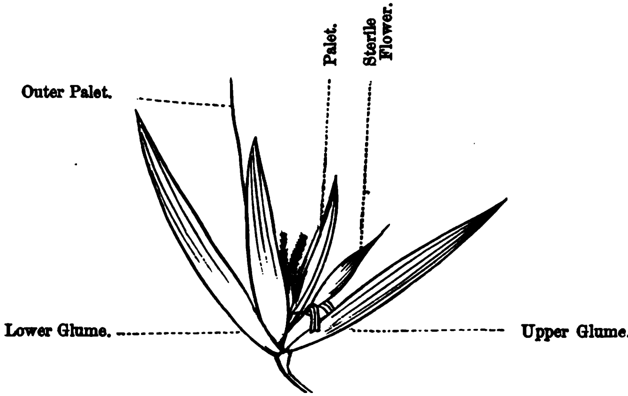


Fig. 342.

In Fig. 342 are seen the palet, squamulæ, stamens, and pistil. The oat may be thus described:

Inflorescence?	Panicle.
Glumes?	2.
Outer palet?	1.
Palet?	1.
Lodicules?	2.
Stamens?	3.
Styles?	2.

CHAPTER XIV.

FLOWERLESS PLANTS.

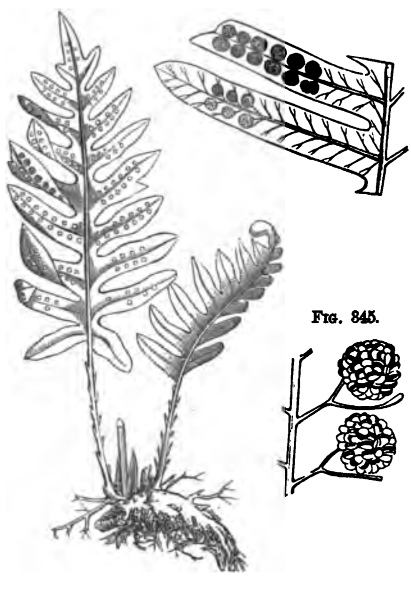
EXERCISE LVIII.

Ferns.

You have often seen dense, green patches of plants, more or less resembling Fig. 343, and called *brakes*,

FIG. 343. FIG. 344.

FIG. 345.



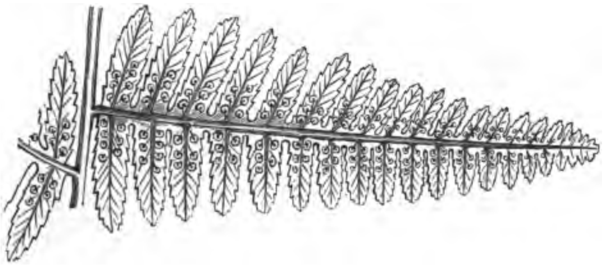
or *ferns*. They seem, when growing, to be all leaf and no stem; but you see in the figure that the stem

is a short, underground rhizoma. In some ferns the rhizoma takes a vertical direction, and bears a whorl or tuft of foliage at the top. Here it gives off single leaves as it advances. Although, in our climate, the stems of ferns are found creeping underground, yet in the warm climates of the tropics they rise in the air, sometimes forming trees, forty or fifty feet in height.

Did you ever see any flowers upon this sort of plant? any thing that looked like fruit? Since studying the Coniferæ, you are aware how very simple and obscure flowers may become, and you will, of course, look very carefully at a plant before deciding that it has none. Gather as many kinds of ferns as you can find, and search for the seed-bearing portions. Meantime you can learn the terms by which their parts are distinguished. They are the following:

The leaf of a fern is called a *frond.* The stalk or petiole of a frond is called a *stipe.* Point out the

FIG. 346.



frond and stipe in the specimens you have gathered. The lobes of a frond are called *pinnæ* (Fig, 344). Subdivisions of pinnæ are called *pinnules* (Fig. 346).

Point out the pinnæ in your specimens. Have you found any in which the pinnæ are divided or lobed by pinnules? Observe the differences of stipe in your specimens. What kind of soil did you find them in? Were they growing in shady or sunny places? Did you observe the way the young fronds were folded in the bud?

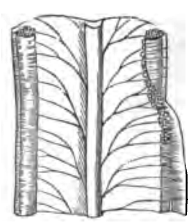
EXERCISE LIX.

Reproduction of Ferns.

Did you find any thing that you could fancy to be a flower, in your examination of ferns? Look them over once more on all sides, and note all appearances that are repeated on different specimens. Observe carefully the under side of the frond, along the veins and the margin. Do you not anywhere find little brown patches resembling the spots seen in Fig. 344, representing magnified pinnæ, or the pinnules of Fig. 346? In Figs. 347 and 348 you see

FIG. 347.

FIG. 348.



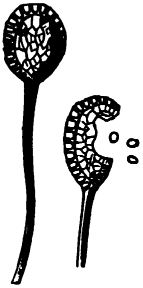
how these spots may be concealed under folds of the margin of fronds.

These brown patches certainly look very little like flowers. Examine them never so carefully with your microscope, you will not find stamens or pistils. And yet these little brown patches answer, in a certain way, to seeds. It is from them that new ferns arise. They are the reproductive parts of this class of plants, and the fronds that bear them are said to be *fertile*. Examine these spots carefully with your magnifying-glass, and compare them with Fig. 345 or Fig. 349. The small, brownish clusters of fruit-dots seen on the under surface of fronds, in rows along the veins, or on the margin of the pinnæ, are called *sori*, and a single cluster a *sorus*. The scale or protective covering of a sorus, seen in Fig. 349, but absent in Fig. 345,

FIG. 349.

FIG. 350.

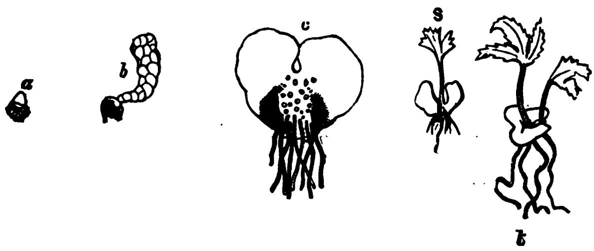
FIG. 351.



is called an *indusium.* This organ is still more plainly seen in Fig. 350.

In the sorus (Fig. 350) you see little, peculiar-looking bodies escaping from beneath the indusium. Each of these cell-like bodies, of which the sorus is composed, is known as a *spore-case, sporange,* or *theca.* They are sometimes stalked, as seen in Fig. 351. The singular-looking band around them is an elastic membrane, which bursts when they are mature, and thus the spores contained in the spore-case escape (Fig. 351). It is from spores that ferns arise, but by a process more like budding than like the sprouting of a seed. When a spore commences to grow, appearances like those represented in Fig. 352

FIG. 352.



may be observed. The growth begun by a spore, as at *a*, and seen more advanced at *b*, is shown, at *c*, expanded into a leaf-like body, called a *prothallus,* which gives off roots at the under surface. Among these roots may be found certain bodies, analogous to the stamens and pistils of flowers, and called the *antheridia* and *pistillidia.* It is not until these bodies have matured and done their work that the young fern appears. If there is any thing like

flowering in the history of ferns, it is the prothallus produced from the spore that bears the flowers, and from these produces the young fern as seen at *s*, and the same, still more developed, at *t*. It would be very absurd to regard the spore as seed-like when it produces the flower, instead of being produced by it. This matter will be more fully explained in Course Second.

EXERCISE LX.

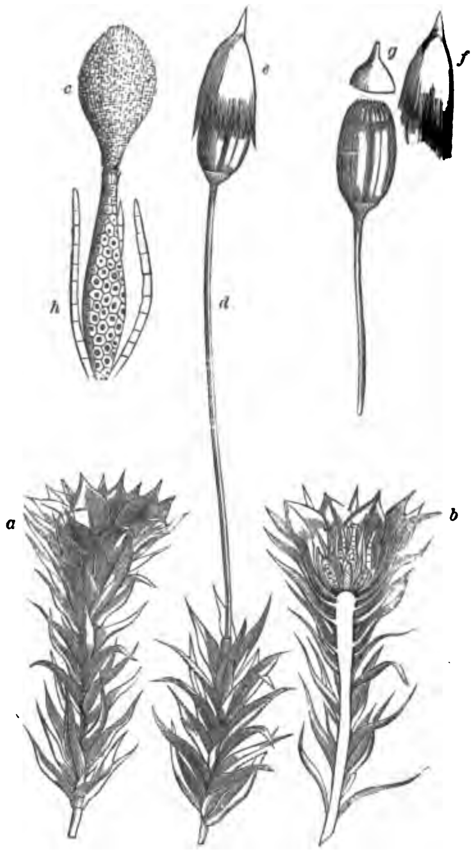
Mosses.

In place of flowers, mosses have *antheridia* and *pistillidia*. These plants may be either monœcious or diœcious. Fig. 353 represents a moss having its antheridia and pistillidia on different plants.

At *a* you notice a moss-plant with sessile leaves and unbranched stem, ending in a sort of rosette, which is seen in section at *b*, where you may observe the peculiar cylindrical bodies growing among the leaves. These are *antheridia*. One of these bodies, detached and much magnified, is seen at *c*. The stalk-like bodies accompanying the antheridia (*h*) are called *paraphyses*. They are not well understood, but are thought to be abortive states of the *antheridia*. At first these little organs contain mucilage, but, when mature, their contents, seen escaping at *c*, are granular, and each of the little ejected cellules sets free an active *antherozoid*. (*See* page 259.) Sometimes the leaves that surround the antheridia grow together into a kind of cap called a *perigone*, and in

monœcious mosses, the antheridia and pistillidia are often found within the same perigone.

FIG. 358.



The *archegone* or *pistillidia* of mosses also arise in clusters of leaves, and are cell-like bodies, having

a cap or *epigone* of the same nature as the perigone of antheridia. But the pistillidia bursts its cap, leaving part of it as a sheath below, and is carried up on a stalk (*d*), at the top of which is seen an urn-shaped body of curious structure, called a *sporange* (*e*).

SETA.—The stalk of a sporange (*d*).

VAGINULE.—The collar or sheath at the base of the seta, resulting from the bursting of the epigone.

CALYPTRA.—The cap or hood of a sporange, shown at *f*, and seen in place at *e*.

OPERCULUM.—The lid of the sporange (*g*), seen when the calyptra is removed.

PERISTOME.—A single or double fringe of teeth around the mouth of a sporange. It is sometimes altogether absent. These teeth vary very much in number, but are always either four or some multiple of four.

ANNULUS.—An elastic ring sometimes found in the mouth of a sporange.

SPORES.—The ripened contents of the sporange.

EXERCISE LXI.

Fungi.

The common mushroom, or toadstool, as children call it, is a well-known example of this group of flowerless plants. It is found everywhere growing upon decaying organic matter. If, in gathering specimens for study, you break them off above the surface of the ground, you will leave the plant itself

behind, and bring only the fruit. The part concealed in the rich mould, or spread on its surface, is a tangled mass of filaments that you might mistake for fibrous roots; but it answers to the root, stem, and leaves of higher plants. This portion of the plant is called the *mycelium*, represented by the root-like fibrous portion of Fig. 354.

FIG. 354.

When you are looking for the mycelium of mushrooms, observe the *young* fruit just appearing above the surface. You may often find it in clusters, in all stages of growth, in rich mould, or on decayed logs or stumps.

Fig. 354 represents a full-grown mushroom and several younger ones at different periods of development. The younger ones are smooth, globular masses, but, as they get larger, the outer wrappage breaks, as you see at the right in the figure, and reveals a stem with an umbrella-like cap. The ring around the stalk, seen in the full-grown specimen, shows where this covering, called the *volva*, was attached. The stout stem is called a *stipe*, and its cap the *pileus*. Along the under surface of the pileus you see numerous thin plates, called *gills*, and it is

within these plates that the spores are found, many thousands occurring on the gills of a single mushroom.

Puff-balls are mushrooms without the stem and pileus. The "smoke" which escapes when they are broken consists of spores, which are so exceedingly small that they may penetrate everywhere. A few species of fungi are good to eat, but many are poisonous, and to be avoided. Yeast, mildew, smut, mould, and dry rot, all belong to this group of plants.

FIG. 355.

The gray, yellow, or greenish, crust-like layers that are seen on stones and the bark of trees, on old walls, and in rocky places, are a low form of vegetation, called *lichens.* They have little distinction of parts, except that of upper and under surface, and certain specialized places in which spores are formed. *Algæ*, or the sea-weed family, is another order of flowerless plants, which contains many fresh-water species. The green scum seen on the surface of stagnant water is one of the lowest forms of fresh-water algæ, called *conferva.*

COURSE SECOND.

VEGETABLE ANATOMY AND PHYSIOLOGY.

THAT branch of the science of botany with which you have been thus far occupied is called *Organography*, which describes the external parts of plants in respect to their forms. You are now to take up the study of vegetable *anatomy*, or the minute structure of plants as revealed by the microscope. These two departments of the science constitute *structural* botany, in which the plant is regarded without reference to its activities. The study of the plant in action, or vegetable physiology, will conclude the volume.

To study the internal parts of plants by direct observation you must have a microscope that will magnify from forty to eighty diameters. You may read descriptions, and see pictures of cells, fibres, and vessels, and their relations in the living structure, and so get an idea of the subject, which is better than none at all; but knowledge so gained is very imperfect, from its vagueness and want of reality. Besides, when statements are taken at second-hand, the learner loses the educational effect of search and discovery, and has not the interest or enthusiasm which is awakened by impressions of the things themselves.

CHAPTER XV.

THE INTERNAL STRUCTURES OF PLANTS.

EXERCISE LXII.

Cells and Cellular Tissue.

ORDINARY plants differ so little in their inner structure, that almost any specimen will furnish you with examples of cells and tissues; but these elements are more conspicuous in some parts of plants than in others. For instance, make a thin cross-section of the pith of elder, or, if you cannot get this, of the pith of any young twig. A sharp, thin-bladed knife, and some practice, are needed to make the slice so thin that it will distinctly show the structure. Put the slice upon the slip of glass provided for the purpose, and add to it a drop of water. Place over

FIG. 356.

it a thin glass cover, which must first be permitted to rest on one edge, and then be slipped down carefully to push out air-bubbles. Under the microscope the slice presents an appearance like Fig. 356.

In the same way prepare and examine slices of melon, potato, cabbage-stalk, apple, orange-pulp, or any ripe fruit, or succulent stem, or young, growing shoot.

Take a little of the pulp of boiled rhubarb on the end of a needle, and put it upon a slip of glass, adding a drop of water. Under the microscope you will again see just such appearances as were presented by the elder. Place thin petals under the microscope, and observe their structure.

These walled spaces, of varying shape, and of about the same diameter in all directions, are called *cells*, and the mass of substance they form by their union is *cellular tissue*.

Cells consist of an outer membrane, or wall, that contains various liquid, semi-liquid, and solid matters. They vary much in size. The largest cells of the pith are $\frac{1}{30}$ of an inch in diameter, though a cell $\frac{1}{200}$ of an inch in diameter is a very large one. Those of ordinary cellular tissue are about $\frac{1}{400}$ of an inch in diameter. The very smallest vegetable cells are from $\frac{1}{4000}$ to $\frac{1}{6000}$ of an inch in diameter. The shape of the cells of cellular tissue depends upon the pressure around them. When there is no pressure, they are round, or egg-shaped; but, if they crowd each other as growth goes on, they become many-sided, or polyhedric.

Cellular tissue is said to be *regular* when its cells are cubical; *prismatic*, when they are elongated; *tabular*, when they are flattened; and *muriform*, when they look like courses of brick in a wall. All cellular tissue, whatever the form of the cells, is called *parenchyma*.

When the cells of cellular tissue, or parenchyma, are crowded, they may fit exactly against each other, and leave no unoccupied spaces (Fig. 357). We have then *complete parenchyma.*

When the walls of cellular tissue are round, so that spaces are left between the points of contact

Fig. 357.

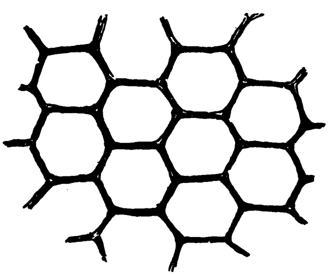
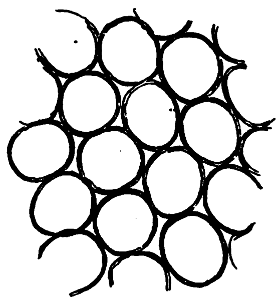


Fig. 358.



(Fig. 358), the tissue is called *incomplete parenchyma.* The spaces between the cells in incomplete parenchyma are called *intercellular spaces. Lacunes* are formed when an intercellular space is produced by the destruction of cells from any cause.

EXERCISE LXIII.

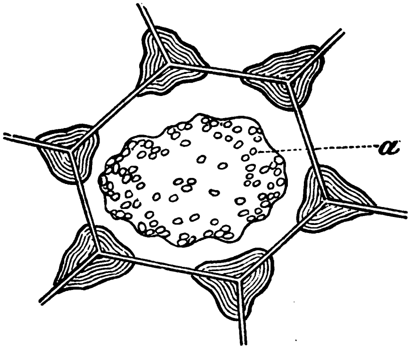
Structure and Production of Cells.

Experiment.—Apply a weak tincture of iodine to a little of the green tissue of a leaf, or other succulent vegetable matter. The contents of the cells are first colored brown, and presently they shrink away

from the cell-wall, forming a mass in the interior, as shown at *a* (Fig. 359). Or you may get the same result without discoloring the cell-contents, by placing the green tissue or pulp of fruits, or leaves of mosses, in dilute nitric or muriatic acid.

Take, with care, a bit of the skin from a vigorous, hairy leaf, as the nettle. Put it upon the glass slide with a drop of water, and examine the appearance of the hairs under the microscope. Each hair, you see, is a leaf-cell grown out into the air. Now drop upon

FIG. 359.



it spirit of wine, or something that will kill the cell, and, after a time, the cell-contents will separate from the cell-wall, as shown in Fig. 359.

As to the cell-wall, it is at first a moist, soft, thin, uniform membrane, which allows the free passage of water through its substance; but usually a second membrane appears, lining it on the inside, though it does not form a complete and continuous lining. It is broken in many places, making the cell-wall thick

here and thin there. As the cell grows older its wall thus increases in thickness and density, and often by these changes opposes the passage of water through it.

Under the most powerful microscopes, no appearance of porosity is seen in the primitive cell-wall. But the breaks of its lining membrane make it thin in some places and thick in others, and these broken places appear as markings on the wall. When they are minute and frequent, the cell-wall looks dotted, and such cells are called *dotted cells* (Fig. 360).

FIG. 360.

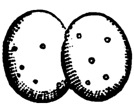


FIG. 361.

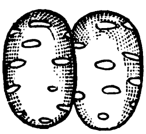
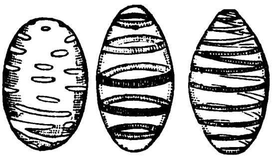


FIG. 362.



When the breaks are little slits, or bars (Fig. 361), we have what are called *fenestrated* cells.

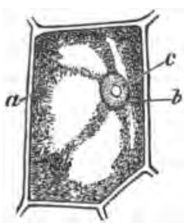
When the internal membrane breaks up to a considerable extent, the resulting fragments take on various shapes of bands, rings, and spiral markings, and so form what are called *reticulated*, *annular*, and *spiral* cells (Fig. 362).

In most cells that enter into the permanent substance of a plant, the cell-wall continues to thicken long after it has ceased to enlarge. Sometimes a third and even a fourth layer is developed within the cell. These layers are generally moulded exactly upon the others, so that the thin places remain, and the thick grow thicker.

But the life of the cell is not in its membranous wall, which is rather a skeleton, or framework, for the support of the vital parts.

That portion of the cell-contents which lies next the cell-wall is a semi-fluid, turbid substance, always present in young, growing cells, and such as are reproducing other cells, or doing work of any kind. The name of this substance is *protoplasm*, and it is found wherever there is life. It is not a membrane, but a mucilaginous substance, which moulds itself upon the cell-wall, is flexible, ductile, and not unlike the condition of glass at the instant the glass-blowers mould it. In Fig. 363 is seen the cell-wall (*a*), with its lining of protoplasm (*b*). The round body (*c*) in the interior is the *nucleus* of the cell, within which the nucleolus is also shown as a white spot. In young cells the protoplasm and nucleus nearly fill the space, but the cell-membrane is kept expanded by the *sap*. *Protoplasm* does not dissolve in water, or even mix with it. It has the power of contractility, and, in living cells, is constantly in motion. When highly magnified, it is found to contain a vast number of minute granules, which circulate in streams, having particular directions. This beautiful phenomenon of circulation in cells is well seen in the jointed hairs which cover the stamens of the Virginian spiderwort. It seems to result from a property, possessed by all protoplasm, of constant motion in some form or other.

FIG. 363.



CELL-PRODUCTION.—The growth of plants takes place, either by the expansion of existing cells, or by the formation of new ones, and principally by the latter method. "The contents of the cells of the growing part divide into two, and between the halved contents there forms a thin layer, which divides each cell into two distinct cells. The new cells, then, increase in size until they become as large as their parent-cell, when they each divide again, and the process is repeated. The process is modified according as the cells are to lengthen or to remain short."

The rate at which cells are formed may be gathered from such a fact as the growth of a huge puff-ball, sometimes nearly a foot across, in a single day. In this sudden growth it has been estimated that 300,000,000 or 400,000,000 cells are produced in an hour. Century-plants, growing in conservatories, after many years produce a flowering stem six inches in diameter. The entire vigor of the plant is devoted to the growth of this stalk, which ascends at the rate of a foot in twenty-four hours. Estimating the cells at $\frac{1}{300}$ of an inch in diameter, there are formed more than 20,000,000,000 a day.

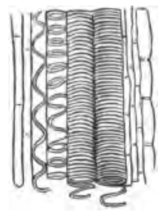
EXERCISE LXIV.

Vessels or Ducts, and Fibres.

EXPERIMENT.—Take some of the boiled pulp of any soft vegetable substance, as rhubarb, that can be picked to pieces with needles. Put a bit of this

stringy pulp in a little water, and separate from it some of its smallest threads. Put these on the glass with a drop of water, and arrange the thin cover as

FIG. 364.



before. When magnified, you will see among the cells long, tube-like bodies, having their walls marked with rings and spirals, such as are shown in Fig. 364.

FIG. 365.

Examine slices taken both across and lengthwise from the young, succulent, fast-growing shoots of any plant; from the ribs, petiole, or veins of leaves; from parts of the flower, of roots, or of underground stems. By carefully looking at these sections, you will again see embedded among the cells tubes of varying length, and with different aspects. These tubes are called *ducts.*

EXPERIMENT.—Take a small bit of soft wood, half the size of a pea, and boil it in a few drops of nitric acid for several seconds. Rinse it carefully with water three or four times, to cleanse it from acid, and pick it to pieces, as you did the fibre of rhubarb. Examine a minute portion of this wood under the microscope. You will

see long, tapering threads overlapping each other, something like Fig. 365, and called *fibres.*

Vessels, or *Ducts*, as Prof. Gray prefers to call them, are continuous tubes of considerable length, of which the walls are never smooth, but marked with dots, bars, rings, spirals, etc. They are sometimes cylindrical, and sometimes tapering in form, and contract a little from place to place along their length, as seen in Fig. 366, where circles are formed by the constriction. The meaning of these constrictions may be gathered from the following

FIG. 366.

EXPERIMENT.—Select from vegetable pulp some of the stringy portion containing vessels, and pour upon it boiling water, sharpened by a few drops of nitric acid. The vessels will break up into fragments at the places of these circles. At these points, also, you will find partitions across the vessel, more or less perforated and broken, or membranous folds, that may come from the breaking of these partitions. Hence, it appears that a vessel is formed from a row of cells, placed end to end; the partitions, which at first separated these cells, being more or less completely removed.

Vessels, or ducts, like cells, are named from the markings on their walls. There are dotted, barred, spiral, and annular vessels (Figs. 367–370). Fig. 371 represents scalariform ducts, so named from the ladder-like markings on their walls.

Fibres, also, are produced from cells; they are cells altered in certain ways. All vegetable tissue is at first cellular, and it is by the elongation of cells

into fibres, as well as by their union and modification in various ways, that all the elements of vegetable structures are produced.

FIG. 867.


FIG. 868.


FIG. 869.

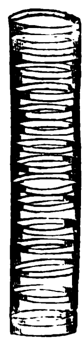

FIG. 870.


FIG. 871.


Fibres vary in length, and their walls thicken with age by the deposit upon their interior of new layers filling up the cavity. As long as any cavity remains it will be round, while, by pressure, the external wall becomes flattened and prismatic (Fig. 372). In fibrous tissue (Fig. 373) you see the tapering, overlapping extremities, making the texture close and solid. The largest fibres of wood are found in trees of the pine family—cone-bearing trees—where they are as much as $\frac{1}{300}$ or $\frac{1}{200}$ of an inch in diameter. Their size varies in different families of

plants as much as does that of cells. The fibres of basswood are about $\frac{1}{1500}$ of an inch in diameter.

FIG. 372.

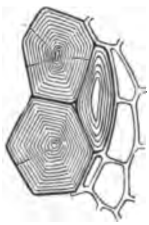
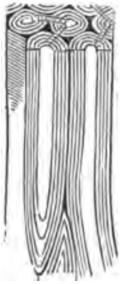


FIG. 373.



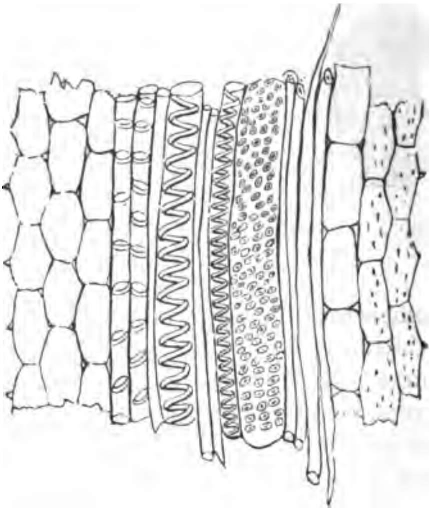
But the compactness of fibrous tissue depends more upon the thickness of the walls of its fibres than upon their fineness. Hence the density of the old heart-wood of trees, where the cavities of the fibres are entirely filled by deposited matter. Woody fibres rarely exceed $\frac{1}{12}$ of an inch in length, while the fibres of some kinds of wood are only $\frac{1}{100}$ of an inch long.

Tissues formed of elongated cells, particularly of such cells as have tapering extremities, are called *prosenchyma*. The cells of prosenchyma vary much in length and proportions. Woody tissue is made up chiefly of prosenchyma, yet some wood consists largely of parenchyma, in which the cells have become solid by the deposits upon their interior. At first the elongated cells of wood have their ends nearly square, but, as they lengthen and crowd each other, they become wedge-shaped.

The blending of cells, fibres, and vessels, in the tissues of a plant, is shown in Fig. 374, which repre-

sents a greatly-magnified section of the Indian reed. At the left you see cellular tissue, or parenchyma; then annular and spiral vessels, dotted ducts, and fibres.

Fig. 374.



Again, Figs. 375 and 376 are drawn from sections of the wood of the plane-tree. In Fig. 376 you see the open mouths of the ducts, which are shown vertically in Fig. 375.

Experiment.—To observe the coiled threads upon the walls of vessels, tear gently the young shoots of the rose-bush or elder, or carefully pull asunder the petiole, or one of the veins of a strawberry-leaf, just breaking the cuticle, and only stretching the internal parts. Or, even, if the parts are quite separated, you may see with the naked eye, at the point of fracture,

the broken, mutilated coils of spiral vessels. The uncoiling, spiral thread is thus easily seen, but the wall of the vessel is difficult to find.

FIG. 375.

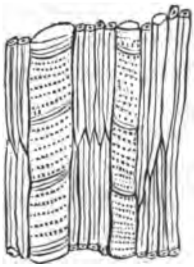
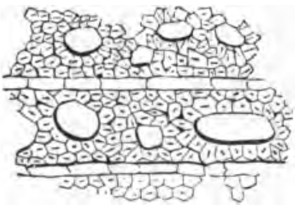
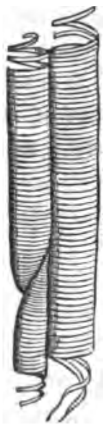


FIG. 376.



These membranous threads of spiral vessels continue, without interruption, from one end of the vessel to the other. In most cases they are simple, but sometimes they are found double (Fig. 377), triple, etc. Even twenty juxtaposed threads have been seen forming a ribbon, and unrolling all together. Spiral threads, that at first were simple, sometimes split into several very fine threads. The spiral thread is neither tubular nor channelled; it may be round, flat, or square. The markings of annular vessels, like Fig. 377, and vessels that have at the same time both annular and spiral threads (Fig. 369), reticulated, scalariform, and dotted vessels, are produced in the same way as are similar markings upon cells, as explained on page 199.

FIG. 377.



When you break a stalk or leaf of milkweed, let-

tuce, dandelion, etc., there exudes a milky sap, called *latex.* There is a peculiar system of vessels containing this milky juice, known as *laticiferous* vessels. They form an irregular net-work, as seen in Fig. 378. It is thought that these so-called laticiferous vessels are not true vessels made up of cells placed end to end, but only intercellular spaces with walls formed by a deposit from the fluid that fills them. They never have markings upon their walls like the vessels we have been studying. When young, laticiferous vessels are extremely small, averaging less than $\frac{1}{1400}$ of an inch in diameter, and can only be seen under high magnifying powers. Old vessels, when swollen from accumulations of their milky sap, are more apparent. As you see by Fig. 378, they are cylindrical, and the branches are as large as the veins, forming a sort of net-work. But this kind of vegetable structure is not well understood.

FIG. 378.

EXERCISE LXV.

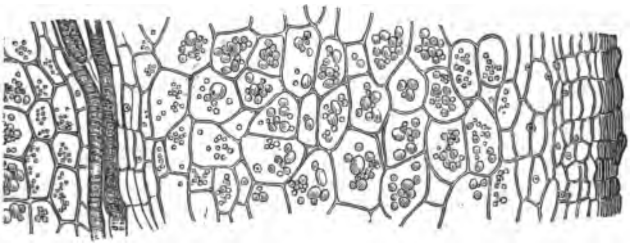
The Contents of Cells.

The contents of cells vary with their stage of growth. When very young they usually contain only the nucleus and protoplasm, but, as they approach

maturity, various substances are found within them, of different kinds and amounts in different species of plants.

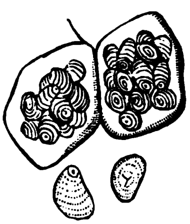
Look at a section of potato under the microscope, and observe the minute grains within the cells. Compare your specimen with Fig. 379. Fig. 380 represents some of the cells more highly magnified.

FIG. 379.



EXPERIMENT.—Place upon the freshly-cut surface of potato, apple, or almost any fresh vegetable, a drop of tincture of iodine. These starch-granules will be colored violet, indigo-blue, or deep-blackish blue, depending upon the strength of the solution used. If there are albuminous granules in the cell, they will be colored brown or yellow by the iodine. By this means the contents of the cell are made more distinct, and the cell-wall is rendered more obvious.

FIG. 380.



Starch-grains are either irregular, spheroidal, or egg-shaped bodies (Fig. 380), having their surfaces marked with concentric circles around points. These

circles indicate so many layers superposed around a little kernel indicated by the central point.

In looking, with the microscope, at sections of leaves, you will see gelatinous flocks of green matter swimming in the colorless liquid of the cells, or deposited on the cell-walls and grains of starch. This substance, to which vegetation owes its green color, is called *chlorophyll*. The yellow coloring-matter of plants is like chlorophyll in every respect, except its color, but the red, violet, and blue coloring-matters are always liquid.

The colorless sap of plants, which fills the cells and vessels, holds in solution all the materials of cell-growth, and of the substances contained in cells. Sugar, dextrine, and gum, dissolved in water, are found in the cells, the intercellular spaces, and lacunes, but, being held in solution, they cannot be detected by the microscope. The intercellular spaces, also, frequently contain air. The fixed oils found in seeds and fruits, and other parts of the plant, form isolated globules, that, by pressure, flow together into large globules. Essential oils, turpentine, and caoutchouc, are usually accumulated in intercellular cavities, or given off at the surface when the plant is wounded.

Various mineral matters are also taken up by the roots from the soil, dissolved in water, and deposited in the structure of the plant. They occur sometimes in the crystalline form in cells. Indeed, it is said that almost every herbaceous plant contains them in more or less abundance. Fig. 381 represents cells of rhubarb, from one of which needle-shaped crystals, called *raphides*, are being ejected. Cells of this kind in the stalks of rhubarb, when moistened with water,

become distended so as to burst, and force out the contents, as here shown. Cells with similar contents are also found in the leaves of four-o'clock, Indian turnip, and calla. These cell-crystals are sometimes agglomerated into masses of angular crystals (Fig. 382).

FIG. 381.

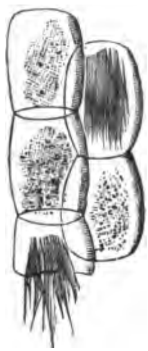
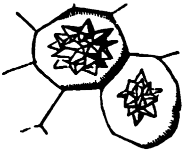


FIG. 382.



That these crystal are formed in the cells is proved by the fact that the shape of the cell determines the form of the crystal. *Silex*, the substance known everywhere as sand, exists, dissolved, in the sap of plants, and is deposited in the stalk of grains in such quantities as to give them the requisite stiffness.

CHAPTER XVI.

THE STRUCTURE OF STEMS.

Now that you have seen the various kinds of cells, fibres, and ducts, and the tissues they form, the next step is to discover how they are put together in the construction of roots, stems, leaves, flowers, fruit, and seeds. To do this we begin with the embryo, and trace its development from germination to maturity.

As the growing radicle, the chief part of the embryo, from which roots, stem, and leaves proceed, is itself stem, we will study the stem first.

EXERCISE LXVI.

Structure of Dicotyledonous Stems.—First Year's Growth.

The monocotyledonous embryo starts with a single lobe, turned a little to one side of the plumule, while the dicotyledonous embryo develops two opposite lobes, spreading away laterally from the plumule. This is but the beginning of a series of differences in structure, which these two classes of plants will present as growth proceeds; hence, they must be studied separately. We begin with dicotyledons.

You are familiar with the succession of *external* appearances presented by the growing plantlet. In Fig. 383 (Gray) you see the part which was the embryo ending above, in the plumule, and below, in the root.

The plant is again shown in Fig. 384 (Gray), after the production of two internodes and two pairs of leaves. The stem still ends with a bud, and the root

FIG. 383.

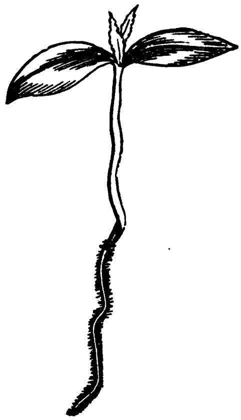
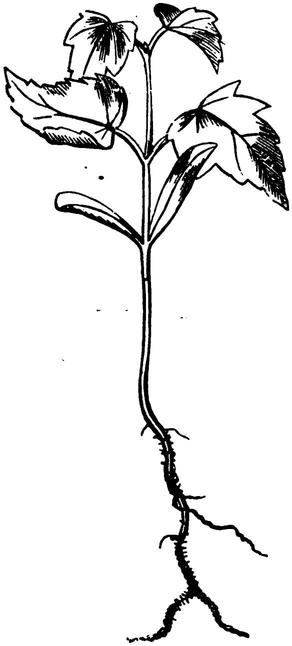


FIG. 384.

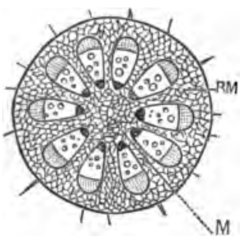


has undergone further development. Now, what *internal* changes have accompanied these external ones?

Cells have elongated into fibres, or united into ducts, and, if we examine a thin section of a young stem, we may observe the way in which these elements are arranged. Whether we take our section from a sprouting maple, which would represent the woody plants of temperate regions, or from a sprout-

ing melon, as an example of herbaceous ones, the appearances at first presented would be nearly the same. Fig. 385 represents a section of the stem of a melon. You see it is a mass of cellular tissue, with several wedge-shaped bodies, forming a circle midway between the centre and the circumference. Make such a section of a young dicotyledonous stem, and observe it with your microscope. Look for the central cellular portion called the *pith*, marked M in the figure. Observe that the outer portion is cellular, and that central and outer cells are connected by cellular strips (R M), which separate patches of denser matter. If you make a vertical section through some of these denser patches, you will find them largely composed of fibres and ducts.

FIG. 385.



Passing from the centre outward, the parts you have noticed are the following:

PITH, or MEDULLA.—The central cellular portion (M, Fig. 385).

MEDULLARY RAYS.—The radiating cellular bands that connect the pith with the circumference (R M).

WOODY, or FIBRO-VASCULAR BUNDLES.—The wedge-shaped bundles of fibres and ducts.

CORTICAL LAYER.—The green cellular envelop of the other parts.

Carefully peel off some of the skin from the same stem, and examine it under the magnifying-glass. You see it consists of flattened, irregular cells, closely

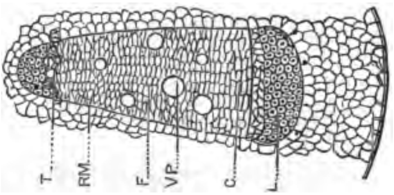
united into a firm membrane. This is the *epidermis*, and, excepting the stigma, it covers all the parts of a plant exposed to the air. By suitable means the epidermis may be separated into two parts, the outer of which is not cellular, and exists sometimes in the lower plants when the cellular portion is wanting. A great French chemist, named Frémy, has shown that it is like caoutchouc, and is named the cuticle.

EXERCISE LXVII.

Structure of a Woody Bundle.

As the woody bundles of dicotyledons are essentially alike, and as they make up the main substance of the stem, we shall get the best idea of stem-structure by observing their composition. Fig. 386 repre-

FIG. 386.



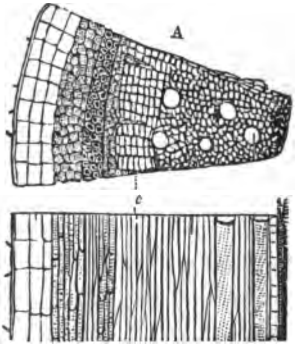
sents a highly-magnified section of one of these bundles, with its surrounding cellular tissue. Observe the region marked C. It is made up of greenish cells of extreme delicacy, and it is from these cells that all the other parts are produced. New cells are constantly forming here, and old ones are changing

into fibres and vessels of various kinds. This is the *cambium* layer. Outside of this layer, and by a transformation of its outer cells, the bark is formed; within the circle made by the cambium and by transformations of its inner cells wood is produced.

The narrow end of this woody bundle, which lies next the pith, and is marked T in Fig. 386, consists of spiral ducts and thick-walled fibres; between these and the cambium layer is the true woody region, comprising about half the bundle. It is made up of woody fibre, with annular, barred, and dotted ducts interspersed. The line R M points to the medullary ray, F to the woody fibres and small annular fibres, V P to large ducts of various kinds. Beyond the cambium we come upon L, the inner bark, or liber, and then follows the outer bark.

The lower half of Fig. 387 represents a vertical

FIG. 387.



section of the woody bundle shown in the upper half of the picture. Observe in the horizontal section the cambium layer, marked *c;* the true wood is seen

passing from A at the right; and the bark, with its different layers, at the left. Trace these different portions in the vertical section.

EXERCISE LXVIII.

The First Year's Growth.—(Continued.)

The number and compactness of the woody bundles in a young stem will depend upon the time of the observation; if it is made early in the season, there will be few (Fig. 388), and their number will increase with the growth and multiplication of the

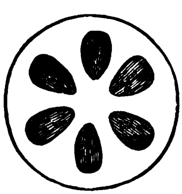


Fig. 388.

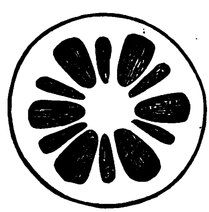


Fig. 389.

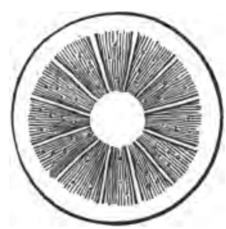


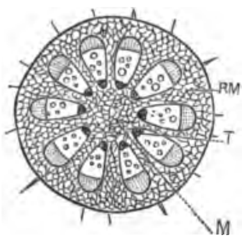
Fig. 390.

leaves. This increase is shown in Fig. 389, where six new bundles are seen inserted between the first six shown in Fig. 388; while in Fig. 390, which represents a woody stem at the close of the year, they are shown filling all the space, except the narrow strips of the medullary rays.

Bearing in mind the composition of a woody bundle, as shown in the last exercise, look again at the section of a dicotyledonous stem during the first

year's growth (Fig. 391). Passing outward from the medulla, or pith, marked M, we come first upon the spiral ducts of the woody bundles, marked T. They form a sort of sheath around the pith, only broken by the medullary rays (RM), and, as they enclose it, they are called the *medullary sheath.* This portion of the woody bundle is continuous with the petiole and framework of leaves.

FIG. 391.



EXPERIMENT.—Divide the bark and most of the wood of a young shoot by a circular cut, and gently pull it asunder; you may detect this sheath by the stretched and broken spiral threads of its fibres.

Outside of the medullary sheath, observe the ligneous fibres, or zone, of true wood. Encircling this is the cambium layer. Up to this point, excepting its somewhat less density, the herbaceous and the woody stems are alike. It is in the portion external to the cambium that we come upon differences. The cambium and bark, it will be seen, are important in plants that are to live over to another year, while they are of little account to the herb, which dies in autumn. In herbaceous stems, as the melon, therefore, the bark consists of simple parenchyma, like that of pith, except that it is of a green color; but in woody stems, as the maple, it takes on a much higher development, and presents important differences of structure. All the while that wood is forming, bark is also being made. That portion of it next the cambium is wrought into woody tissue,

consisting of peculiar cells, called *bast-cells*, of remarkable length and flexibility, and having very thick walls (Fig. 392). They usually form layers like the leaves of a book, and hence this portion of the bark is called the *liber*. The length and toughness of its fibres have led to its use in thread, cord, and cloth. The bundles of bast-cells are always vertical, and are separated by medullary rays, which correspond to those of the woody system inside the cambium.

Fig. 393.

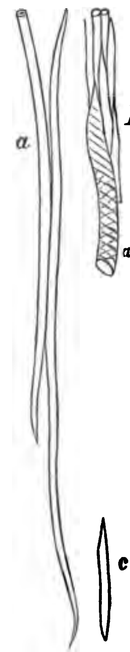
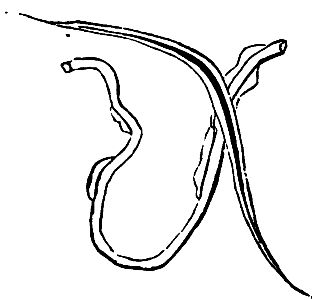


Fig. 392.



Fibres of the liber, or bast-cells, and woody fibres from the linden, or basswood, are shown in Fig. 393 (Gray). *a* is a bast-cell, from the bark of American basswood, while *b* is woody tissue, from the same tree, showing the upper end of a spirally-marked vessel; *c* is a separate cell of the wood. They are all equally magnified.

Besides the immensely greater length of the bast-cells, they have also very much thicker walls than the

fibrous cells of wood. In leather-wood the bast-cells are even longer than those of basswood, being from $\frac{1}{6}$ to $\frac{1}{8}$ of an inch long, and $\frac{1}{2000}$ of an inch in diameter, while those of the wood are not more than $\frac{1}{100}$ of an inch long. Few fibres, however, are as long as those of leather-wood. There are very few plants in which they exceed $\frac{1}{12}$ of an inch in length.

EXPERIMENT.—Strip the bark from various woody twigs, and find the liber. Observe the differences it presents in different kinds of wood. Outside the liber no woody tissue is found, but in very young woody stems this external layer consists of loose, green, cellular tissue. As growth proceeds, this is soon covered with a brown layer of varying hue and thickness, called the *corky* envelop. The cellular layer, thus covered in, is known as the green or cellular layer. The corky envelop and green layer, taken together, are called *suber*.

EXPERIMENT.—Gather the bark of as many different kinds of trees as you can. Separate the suber from the liber. Find the green layer and the corky layer, and note the differences presented by your collection. You will thus associate in your mind the character of the bark with what you know of the other parts and characters of each kind examined. Passing from the centre out, we have—Pith; Medullary sheath; Layer of wood; Medullary rays; Cambium; Liber; Suber, composed of the green layer and corky envelop.

What parts of the stem are cellular? What parts are fibrous and vascular? Do you know which threads are warp and which are woof, in cloth? If

you liken the stem to a woven fabric, which part of it would you say made up the warp, and which part the woof?

EXERCISE LXIX.

Second Year's Growth of Dicotyledonous Stems.

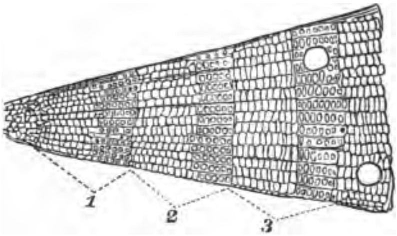
In annual plants, like the melon, the cambium, of course, perishes when the plant dies; but in woody plants this is the region of growth for all after-years. You have seen that, in the primitive bundle (Fig. 386), there are two partial bundles, one of tissues belonging to the woody system, and the other of tissues belonging to the bark. The bark and wood are connected by a delicate tissue of actively-multiplying cells, which may be easily seen with the microscope. As these cells are more gorged in spring, the bark and wood are then more easily separable.

Now, on the second year this cellular zone forms in its interior, or next the wood, a new layer of wood, precisely as in the former year, by the elongation of some of its cells into fibres, and the conversion of others into vessels, or ducts, while still others form the parenchyma of the medullary rays. On the side of the cambium next the bark there is similarly formed from its cells a second layer of bark, precisely like that of the first year. The new layer of bark and the new layer of wood are, as before, transformed cambium, but they are always separated by the true cambium layer of vitally-active cells.

The changes produced by age upon the woody system of the stem, besides its annual addition of a woody layer, constituted as above described, are, first, loss of color of the cells of the pith, which at last dry up, and lose all vitality; the thickening of the wood-fibres by internal deposit, while, at the same time, they take on a dark color, and become *duramen*, or heart-wood.

Can you see any reason why the yearly layers of wood should form rings so distinct that they can be counted, and the age of the tree determined? It is because the wood formed in the first part of the year, which is, of course, placed next the old ring, is more porous, and often has a larger number of ducts with large mouths than the wood formed later in the season. This is shown in Fig. 394, where the annual

FIG. 394.

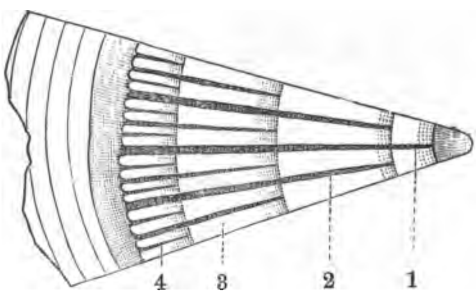


layers are marked off and numbered, and you see that the inner portion of the layer is more porous than the outer.

Now, the new layer of wood is moulded exactly upon the last year's layer, so that the bundles are separated, as before, by the medullary rays, which

are, of course, continuous with those of the former year, and so extend from the pith to the bark. The woody bundles of the second year are more numerous than those of the first year. If each newly-added portion of the old woody bundle was undivided, there would be the same number of medullary rays throughout the growth of the stem. But, besides the medullary rays that separate the primitive bundles, and extend from the pith to the bark, there arise divisions of each new bundle into two or three parts by series of cells, which are called *small medullary rays* (Fig. 395).

FIG. 395.

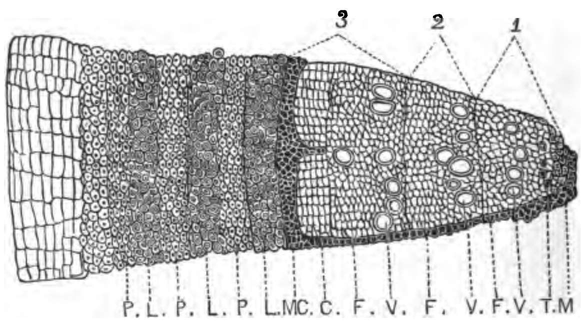


In this figure, representing four years' growth, you can trace the rays of each successive year. There is only one of the first year's growth, and, by the development of this portion of the stem, on the fourth year you see fifteen. So that each year, with the formation of the new woody layer, new medullary rays are also started, which are prolonged on the following years in the same way as the great rays proceeding from the centre of the stem.

In our picture of the woody bundle (Fig. 386) of the first year, the portion next the pith is shown, consisting of spiral ducts; and you saw (Fig. 385) that the spiral ducts of all the woody bundles form a sheath around the pith. But this sheath is not reproduced in after-years. There are no spiral ducts in the wood of the second year. They are never found in woody stems, except around the pith.

The stem, then, is made up of two distinct parts, the wood and the bark. Fig. 396 represents a por-

FIG. 396.



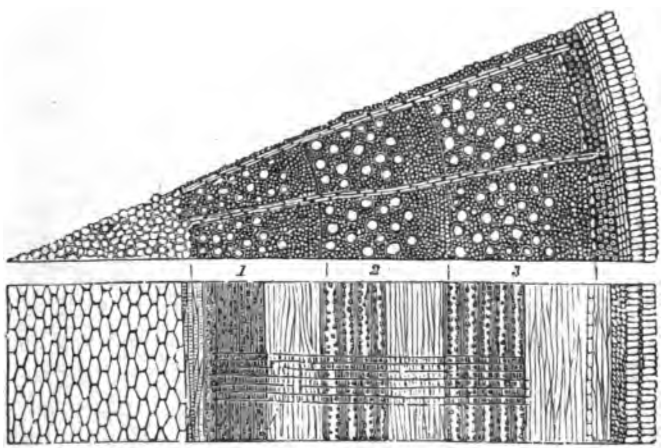
tion of a woody stem three years old. At M, you see the pith; T is the medullary sheath, and V, F, the woody layer of the first year, followed by V, F, V, F, the layers of the second and third years. After the cambium (C) is the green layer of the bark (M C), and the three successive yearly rings of bark, marked L, P, L, P, L, P.

The green layer does not increase at all after the first year, as the corky layer shuts out the light on which its growth depends, and finally it perishes en-

tirely. The corky layer continues to grow for a few years, but it differs in different species. Its cells are powdery in the birch, and so cause the peeling of the more compact layers. The liber continues to grow throughout the life of the tree.

Fig. 397 represents a vertical and horizontal section of a woody stem three years old, in which you can trace the parts we have described.

FIG. 397.



What must be the effect upon the bark of this yearly formation of two new layers within it?

Examine the bark of such trees as you can get at, and point out the results which you think follow from this internal deposit of matter.

In oak and chestnut wood the ducts of the inner portion of each annual layer are large and numerous, while the outer portion of the layer is dense and solid.

In maple and beech the ducts are uniformly distributed, while in pines there are no ducts at all. But the inner and outer portions of each layer are still so different in compactness, that the line which separates the new, large, vigorous cells of the spring growth from the close, fine cells, formed the last of the previous season, can usually be distinctly seen.

But, if the wood of pines has no ducts, it still presents a peculiar structure. It is composed wholly of dotted fibres, and the dots are produced by little hollows in the sides of the fibres, like the cavity of a watch-glass, these hollows being so placed that, when fibres come together, one concavity answers to another (Fig. 397*), making a lens-shaped space, like two watch crystals, so placed that the concavities face each other. These little disk-like marks are the result of an unequal deposit of the lining material of the fibre, leaving thin places where the wall of the fibres curves inward. This thinness, as the fibre gradually fills up with deposits, produces in the centre of each cup a short canal, opening into its interior. The cavity is usually filled with turpentine, which sometimes finds its way through this canal into the fibre, destroying it little by little, and often producing considerable deposits of resin in the wood of green trees. In all the pine family these marks are on the lateral portions of the fibres, and never on the part toward the centre or the outside of the tree.

FIG. 397.*

EXERCISE LXX.

Stalk of Monocotyledons.

The embryo of the monocotyledon is entirely cellular before germination. Growth commences by the elongation of these cells, and the gradual formation of fibro-vascular bundles. At first the bundles are few, and disposed much as in young dicotyledons, but, in proportion as the leaves develop, these bundles multiply, and are distributed, without apparent order, all through the cellular tissue; they are, however, much more numerous and solid as they approach the circumference of the stalk. Make an horizontal section of the stem of a corn-stalk, and compare it with Fig. 398, where the dots (F) represent woody bundles, and the spaces (M) represent cellular tissue.

Fig. 398.

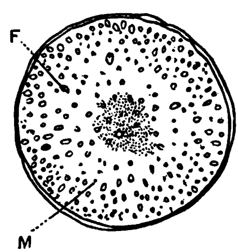
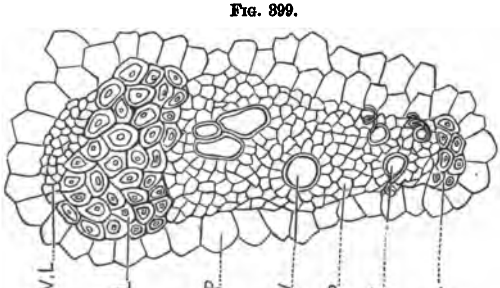


Fig. 399.



If you examine one of these bundles under the microscope, you will find it presenting an aspect like

Fig. 399. That portion of the bundle which looks toward the centre of the stem answers to wood, and the outer portion answers to the inner bark, while the cellular tissue, through which the bundles are interspersed, answers to the medullary rays and pith of the stems of dicotyledons. In Fig. 399 L is a region of fibres, with thick walls and spiral ducts (T). Then, in the midst of cells and fibres (P), we have barred and dotted ducts (V); beyond, at L, are thick fibres, like the liber, and, still outside of these, the laticiferous ducts (V L).

The vertical section of a stem formed from these bundles presents an appearance like Fig. 400. These woody bundles, scattered irregularly through the cellular tissue, remain single and isolated. There is no such thing as a separation of the stem into a woody system, and a region of bark, with cambium interposed, as in dicotyledons. There are differences, however, between the central and exterior parts of the stem, somewhat analogous to these, which we will endeavor to explain.

FIG. 400.

Figs. 401 and 402 will assist in understanding these differences. The dark lines represent woody bundles. Each bundle, traced from above downward, starts from a point on the stalk, where a leaf is inserted, descends obliquely toward the centre of the stem (mark this), then, curving outward, descends obliquely again toward the circumfer-

ence. You see it crossing successively all the bundles situated below it, and older than itself, and taking its place above them.

Now, the differences between the interior and exterior of the stem result chiefly from the changes in composition that each bundle undergoes in its course from its origin at the leaf insertion to its ending in the cir-

FIG. 401.

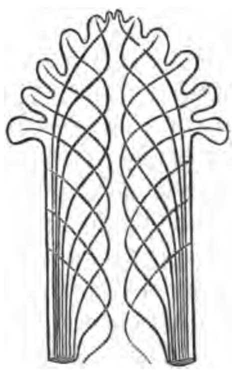


FIG. 402.

cumference far below. In the region of the bundle which descends toward the centre, its woody portion is greatly in excess over the cortical part, while below this region, in the part of the bundle which descends toward the periphery, the cortical part of the bundle greatly predominates, and finally forms almost the whole of it. On approaching the outside, the bundle grows thin, and divides into several filaments, resembling fibrous roots. These filaments interlace with those of neighboring bundles,

and form a zone of a sort of netted liber inside the cellular layer, which serves as bark.

It is thus apparent that the central part of the stem will always be made up of the part of the woody thread in which the wood predominates. This part of the thread is porous, and contains great vessels, so that the centre of the stem is rather cellular and vascular than fibrous. In the same way the peripheral part of the stem always contains, or is made up chiefly of, the part of the thread in which the cortical portion, the bast-cells, or liber, predominate; it is, therefore, more solid. Outside of this is the region where the spongy bundles split and interlace, losing themselves in the bark; so that an horizontal section of a monocotyledonous stem is made up of a central porous portion, a peripheral colored and dense portion, and a zone of a sort of liber exterior to this. In dicotyledons, on the contrary, the old, solid wood is in the centre, or heart, of the stem, and the new, soft wood surrounds it. A monocotyledonous stem presents nearly the same size along its whole length. This is because the woody bundles lessen gradually toward their inferior portion, and are not all collected at the base of the tree, as in dicotyledons.

In monocotyledons, the new wood is formed in the central part of the stem; they are hence called *endogens*, or inside growers, while dicotyledons, which form their new wood in circles outside the old, are called *exogens*, or outside growers.

This is, perhaps, as good a place as any to tell you that all plants that bear their seeds in closed seed-vessels may be divided into two great classes, based upon

characters of seed, stem, and leaves. Their seeds are either monocotyledonous or dicotyledonous. The monocotyledons have stems in which the parts are arranged as we have just shown; they have the endogenous structure, and are hence called *endogens*. Their leaves are also parallel-veined. The dicotyledons, on the contrary, have stems with the exogenous structure, and are hence called *exogens*. They have also net-veined leaves. Now, these characters are almost always combined as here stated. There are dicotyledons with parallel-veined leaves, though they are very rare; but the structure of the stem is characteristic. When you find a plant with a stem having woody bundles surrounding the pith, it belongs to the class of exogens; but, when the woody bundles are seen scattered, without order, through the parenchyma, the plant belongs to the class of exogens. The coniferæ, you remember, are polycotyledonous and naked-seeded, but they form their new wood outside the old, and therefore belong to the exogenous class.

Among the flowerless plants, minute structure also furnishes characters used in classification. The stems of ferns have a mode of growth peculiar to themselves, which has given them the name of *acrogens*, or end-growers, because the new parts are always formed above the old. Mosses, algæ, and fungi, are called cellular plants, being made up of nothing but cells. It is not till we come to ferns in the ascending scale of vegetation, that any thing like true vessels and fibres appear.

The scheme on the following page will show you how these plant-characters are used in separating the vegetable kingdom into classes:

DIVISIONS OF PLANTS INTO SERIES AND CLASSES.

SERIES I.—FLOWERING, or PHÆNOGAMOUS PLANTS, with

Exogenous growth and a dicotyledonous embryo.		Class I. EXOGENS, or DICOTYLEDONS.
	Seeds in a pericarp.	Sub-class 1. ANGIOSPERMS.
	Seeds naked.	" 2. GYMNOSPERMS.
Endogenous growth and a monocotyledonous embryo.		Class II. ENDOGENS, or MONOCOTYLEDONS.

SERIES II.—FLOWERLESS, or CRYPTOGAMOUS PLANTS, with

A distinct axis, or stem and foliage, containing	woody and vascular tissue.	Class III. ACROGENS (ferns).
	cellular tissue only.	" IV. ANOPHYTES (mosses).
No distinction of stem and foliage, but all confounded in a thallus.		" V. THALLOPHYTES (fungi & algæ).

CHAPTER XVII.

THE ROOT.

EXERCISE LXXI.

True Roots and Adventitious Roots.

WHEN the young plant contained in the seed begins to grow, the plumule rises toward the light, while the opposite portion grows downward, and becomes root. Observe in Figs. 383 and 384 that the root, as it increases in length, sends off branches on all sides. Roots formed thus, by the extension and branching of the root-end of the embryo, are called *true roots.*

FIG. 403.

But, in the sprouting of such seeds as the oat or Indian-corn (Fig. 403, from Prof. Gray), the radicle never lengthens; it becomes abortive, and the roots spring from the side of the stem. All roots that arise from the sides of stems, either in germination, or at any period in the growth of a plant, are

called *adventitious roots.* The roots of all monocotyledons are adventitious. Many dicotyledonous plants produce adventitious roots in the course of growth.

EXPERIMENTS.—Place the branch of a willow with its cut end in the moist ground. It will send out roots, and become an independent plant.

Detach a slip of geranium from its parent plant and bury its broken end in moist sand. It will take root, and form a perfect plant.

Observe the roots of Indian-corn, that always arise just above the ground, at the joints, and, growing downward, enter the soil.

Some plants, as the strawberry, that begin life with *true roots*, continue it by means of *adventitious roots.*

Bend over the young branch of a rose-bush, and bury a portion of it in the soil (layering). It will attach itself by means of adventitious roots, and then you may cut its connection with the parent-bush without harm.

Adventitious roots are often found on the stem of climbing plants, giving support to them by adhering to adjacent objects.

Only true roots become tap-roots. When the branches of true roots remain small, the central portion can thicken; but, if they are many and vigorous, the central portion is lost, and the root becomes fibrous. All the various forms of roots depend upon the amount of the branching and the enlargement of its different portions by deposits of food.

EXERCISE LXXII.

The Minute Structure of Roots.

In the germination of dicotyledons the cells of the root-end of the radicle multiply, and the central ones are changed into vessels continuous with those of the stem. The developed root differs from the stem in having neither pith nor medullary rays. Like the stem, its thickness increases by the annual formation of a layer of wood and a layer of bark. Spiral ducts are never found in roots; such fibres and ducts as enter into its composition are like those found in the stem. Its cells are filled with sap and with starch. In monocotyledons the multitude of fibrous roots, which issue from the side of the radicle in germination, are exactly like the stem in their minute structure.

Roots grow in length by additions of matter at the tip, or free end, while the stem grows throughout its whole length. You may test this statement by marking off into four equal divisions, with ink, the parts of the root of a sprouting pea. After leaving it in the soil for three or four days, observe whether the parts have all lengthened to the same extent. It has been calculated that the growth is confined to a space of about one-sixth of an inch from its tip.

FIG. 404.

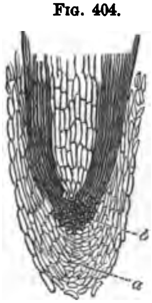


Fig. 404 represents the structure of the growing extremity of roots and rootlets. The darkened cells (*b*) are the region of vital activity;

the dead cells (a) at the extreme end form a sort of root-cap, which protects the living point from injury as it pushes its way through the earth. These dead cells are gradually sloughed off, and replaced by the addition of worn-out cells from within. As these root-tips absorb moisture from the soil, they have been called *spongioles*, though incorrectly.

The surface of the growing parts of roots is often densely covered with minute hairs. Fig. 405 represents a portion of barley-root highly magnified, and you see the hairs are tubular elongations of the outer root-cells. They are more abundant in poor than in good soils. They wither with age, and are replaced by new ones nearer the extremity of the youngest branches and fibres. Pull up a young radish, and observe its surface. Compare it with A (Fig. 406). Rinse away the dirt, and com-

Fig. 405.

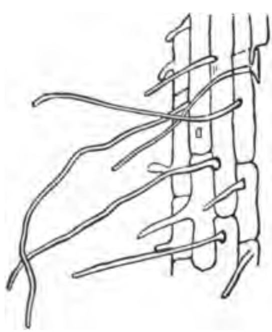
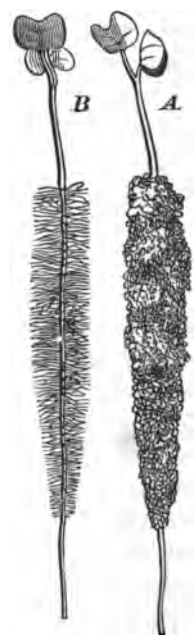


Fig. 406.



pare it now with *B* (Fig. 406). Observe the absence of hairs at the tip.

The first formation of roots in plants is quite independent of the medium in which they exist. But, when the roots begin to act, their growth depends very much upon the medium that surrounds them. If there is food, they grow; and, the more abundant the food, the more they multiply. Those rootlets that come in contact with food, flourish and branch in all directions; while those that find none, cease to grow, or perish. Roots that grow in rich soil are short and very branching; while in poor soil they are long, slender, and have few rootlets.

Most plants with roots adapted to the soil will die if they be left in air or in water; while water-plants die if their roots are placed in the earth. Yet there are some plants which flourish equally well, whether their roots are in the soil, in swamps and marshes, or in water. For instance, rice will grow in pine-barrens, in the tide swamps of the coast, or when its roots are under water throughout its life.

If, however, the seeds of many ordinary plants, when sprouted, have their roots placed in water, care being taken to keep the seed and stem in air, and nourishment be supplied to them, they will produce foliage, flowers, and seeds, the same as if grown in the soil; but, when thus started in water, they will not bear transplanting into soil of the usual dryness. If so transplanted, they may be kept alive by profuse watering until the formation of new roots adapted to the soil. Equal difficulty is met when plants, started in the soil, have their roots placed in water.

EXERCISE LXXIII.

Duration of Roots.

Roots are divided into classes, according to their duration.

ANNUAL ROOTS are those which spring from the seed, and die the same year or season. They are always *fibrous*, arising from numerous divisions of the main or tap root, or, as in all annual grasses, the root is made up entirely of such fibres proceeding at once from the base of the stem.

BIENNIAL ROOTS are those which live through two seasons, dying at the close of the second. You may trace their history in every garden. Plant parsnip-seeds, for instance, which send down their true roots, and form an abundant crown of showy leaves. In the autumn the leaves die, and the tap-roots, filled with nutritious matters, so valuable to man, survive the winter, and in the following spring begin to grow again. But the course of growth is reversed from that of the previous season. Before, it was busy storing up nourishment, which is now spent in forming stem, leaves, flowers, and seeds, with the ripening of which the whole plant dies.

PERENNIAL ROOTS.—These are found in plants which last year after year. In trees and shrubs the same roots live and grow indefinitely; but in herbs that continue from year to year, the active roots of each season die at its close, leaving a stock of newly-formed roots to perform the work of the succeeding seasons. The peony and the horseradish are examples.

CHAPTER XVIII.

THE LEAF.

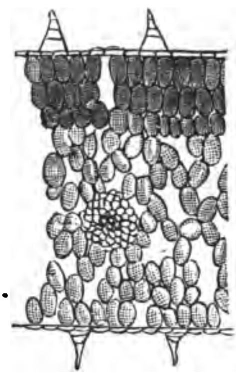
EXERCISE LXXIV.

The Minute Structure of Leaves.

STEMS bear nothing but leaves of some kind or other, for branches are only secondary stems. As leaves are developed upon the stem, we should expect to find them composed of the same elements as the stem. By means of the microscope you may easily determine whether this is so. First examine the structure of the framework of a leaf. Observe a thin horizontal or oblique section, taken from the petiole, midrib, or veins. You will find it composed of fibrous and vascular tissue. Examine a similar slice of the pulp. It consists of cells filled with chlorophyll. The framework is fibro-vascular, while the meshes of the framework are filled with parenchyma. If you should trace the elements of veins and ribs back into the stem, you would find the upper part of this framework connected with the medullary sheath, and you would note that this upper portion, like the medullary sheath, is largely composed of spiral ducts. The lower portions of the framework that appear on the under side of the leaf, you would find to arise from the bark, and to be continuations of the liber. The ribs of most dicotyledons contain much liber, which makes them project on the lower surface.

Are there also differences in the parenchyma of the upper and under sides of leaves? Make a vertical section of the blade of any fresh, ordinary leaf, and observe the structure. Compare it with Fig. 407. Are not the cells much more closely packed on the upper than on the under side? In the figure you see the upper side, composed of three rows of closely-packed cells, placed end to end, while in the lower half the cells are placed irregularly, and the tissue is full of intercellular spaces. You see in this portion of the section the cut-ends of vessels and fibres, where a vein has been severed. This is but one out of many different modes of arrangement; but, in all such leaves as turn one side toward the sky and the other toward the ground, there will be found more or less difference in the structure of the upper and under portions.

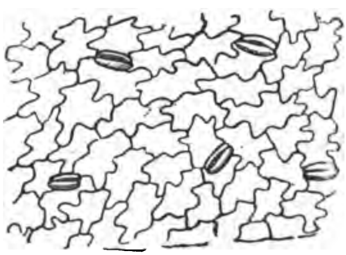
FIG. 407.



Remove a bit of the epidermis, or skin, of a leaf, put it upon the glass, with a drop of water, and examine it with the microscope. Is there any chlorophyll in its cells? How are the cells arranged? Is there more than one layer? Does your specimen exhibit any such appearances as are seen among the cells in Fig. 408? Examine a fresh bit of skin from the under surface of a leaf, and you will surely find them. They are much larger and more numerous in some leaves than in others. Between and underneath these two oblong cells there is an opening

through the epidermis into the intercellular spaces of the parenchyma. These thin-walled cells which guard the opening separate when swollen with moisture, and close together, so as to cover it, when dry. They

FIG. 408.



are called *stomata*, or breathing-pores. In some plants, as the under surface of the leaves of the white lily, there are about sixty thousand of these stomata to the square inch; while in the epidermis of the upper surface there are only about three thousand to the square inch. They vary in different plants from less than a thousand to one hundred and seventy thousand to the square inch of surface. Examine the epidermis from any part of a plant, from the stem, or from sepals, petals, etc. You will often find it furnished with stomata, but you will look in vain for them in the leaves of water-plants.

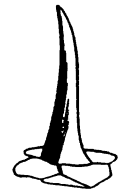
The lower side of the leaf has generally more hairs than the upper side. These hairs are continuations of epidermal cells, and vary much in structure.

Fig. 409 represents a magnified portion of the epidermis of a cabbage-leaf. The oblong slits are stomata, while the pointed, protruding bodies are

hairs in different stages of development. One of these hairs, with some of the cells of the epidermis, is shown in Fig. 410. Hairs composed of a single

Fig. 409.

Fig. 410.



cell are sometimes branched, as shown in Fig. 411, which represents a hair of alyssum; *b* is a transverse section, which better shows the star-like form of the branching. In Fig. 412 (*a*) the hair has the appearance of cells strung together like beads.

Fig. 411.

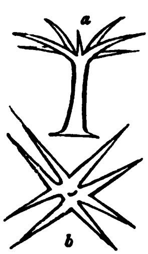


Fig. 412.

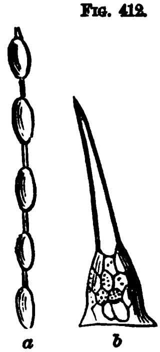


Fig. 413.

Glands are organs that possess the property of secreting; that is to say, of separating some particular liquid from the juices with which they are in con-

tact. They are cellular, and found in the substance of the epidermis, at the base of hairs, as in stings, or carried on the summit of hairs, as in Fig. 413.

Such hairs give to plants an appearance as if covered with little pellucid dew-drops. Look at the hairs of all sorts of plants through the microscope. You will find that glandular hairs are by no means uncommon.

Fig. 412 (*b*) represents a sting. It consists of a single cell, fixed upon a gland, filled with irritating juices. When the hair is disturbed, the liquid of the gland passes through it, and is injected into the disturbing object. Glands are sometimes buried in the bark, but they are always near the epidermis. Cavities containing gums, resins, etc., are analogous to glands, but buried more deeply in the substance of the plant.

Bracts, sepals, and petals, are constructed in the same way as foliage-leaves. Their framework is fibro-vascular, and filled in with parenchyma, which contains various coloring-matters instead of chlorophyll; and over all there is spread a delicate epidermis, more or less studded with stomata. The sepals of monocotyledons are parallel-veined, and those of dicotyledons are net-veined. When petals have long claws, the fibro-vascular bundles traverse them, and separate, to form the framework of the limb, which is composed of spiral vessels and elongated cells.

If you examine the structure of the filament, you will find it composed of a central bundle of spiral vessels and delicate woody tissue, which terminate in the connective. They are surrounded by a layer of cells, covered by the epidermis. The anthers are entirely cellular, the pollen cavities being lined with a

layer of annular, spiral, or reticulated cells, which diminishes in thickness as it approaches the line of dehiscence.

In the structure of a carpel, you find the ovary covered with a double layer of epidermis, enclosing cellular tissue and fibro-vascular bundles that rise from the ovary into the style, not as in the filament at its centre, but at the circumference. The centre of the style is a sort of canal, with cells projecting inward, and its middle filled with moist, cellular filaments, called conductive tissue. This tissue also forms the summit of the style, is destitute of any epidermis, and is familiarly known to you as the stigma.

The fibres of the pistil end in the placenta, which gives off spiral vessels to the funiculus. These vessels terminate in the chalaza of the ovules. Make sections of these parts, and observe the structure for yourselves.

Watch the development of young leaves. Observe at what stage of growth the framework becomes visible; whether the base or apex is formed first; when the stipules appear; when lobes, and the leaflets of compound leaves. How does a leaf look when first visible in the bud? Has it any thing like a leaf-form? Can you find vessels or fibres in its structure while yet in the bud?

Watch the development of the various organs of the flower as the bud is growing. Observe which of its organs appear first. Note whether the base or apex of the petals is formed first. Where the parts of the calyx and of the corolla are grown together, observe whether the tube or the limb is first formed. In regard to stamens, see whether the filament and

anther appear together or in succession, and, if in succession, in what order.

Observe the formations of ovules. A long time before the opening of the flower, you may see a small, round swelling on the placenta, which is the nucleus of an ovule. Soon, around this pimple, there appears a circular rim, which rises toward the summit of the nucleus; and then a second rim appears, growing around the first, and ending by overtaking and surpassing it. These two sacs are not entirely closed, but they leave a circular opening, known to you as the micropyle. Look carefully with your magnifying-glass for the various parts of the ovule while it is growing, and, if you have a microscope, make sections of it, and study its minute structure.

CHAPTER XIX.

THE PLANT IN ACTION.

EXERCISE LXXV.

Absorption of Food by Plants.

As long as a seed is kept dry, the embryo remains unchanged; but, planted in the soil, under the influence of moisture and warmth, it begins to grow—to increase in size and weight, and to develop new organs. At the same time, the rest of the seed withers and disappears. It has been used up by the growing embryo, while rooting itself, and opening its leaves to the light and air. The plant now goes on independently, adding new material to its substance, increasing its size and multiplying its organs.

Now, how do growing plants get the materials for this increase of substance?

This is done in three ways. The first is known as the principle of *capillarity*. This is the attraction of surfaces for liquids, which causes the flow of water upward into sponges and porous bodies generally; and its rise in glass-tubes, with small openings like hairs, and hence called *capillary tubes*. The spongy cellular tissue, without epidermis, at the tips of roots, is surrounded by moisture, which has descended, as rain and dew, through the air and soil, dissolving, in its passage, the various matters which are the food of plants. Just as the water of your wash-bowl wets the whole towel when a corner has been

carelessly left in it, so this water of the soil, entering by the spongioles and root-hairs, passes from cell to cell, and along the vessels and fibres of which the plant is composed.

A second force, which aids in feeding plants, is known as *osmose.* If you place any porous membrane between two liquids of different density, a movement of these liquids through the membrane at once begins. Suppose that, on one side there is syrup, and on the other pure water, there will be a flow in both directions through the membrane; the water will become sweet, and the syrup will be diluted. But the amount of flow is much greater toward the syrup than toward the water, and, if the circumstances permit, the action will continue till the liquids on the opposite sides are alike in density. You may observe this effect in the cooking of berries, as currants, for instance. Here the outer membrane, or skin, of the fruit is between its internal watery juices and the syrup in which it is stewing. This water passes outward, through the membrane, into the syrup of the stew-pan, in much greater quantities than the syrup passes inward, and so the fruit shrivels. On the contrary, if you take dried currants, in which the juices are concentrated, and the fruit already shrivelled, and stew them in pure water, an opposite action takes place. The berry now receives more water than it loses, swells, and assumes its natural shape. In both these cases the principal movement is that of the pure or less dense liquid toward the denser syrup. This is an example of what is called *osmotic* action.

Now, the cells of plants, like the dried fruit in

the water, contain liquids denser than that which surrounds them, and hence the flow is from without inward. When they have thus been filled with water, the liquid they contain is so related to that of the next inner cells that it passes on by osmotic action, thus relieving the outer cells, when they are again ready for a fresh supply from the soil. In this way the action is kept up, from cell to cell, till the liquid has traversed the entire substance of the plant, from the tips of the roots to the uppermost leaves.

The third agent in causing the absorption of liquids by plants is, the evaporation of water by the leaves, and its consumption by the growing buds, which tends to produce a vacuum in the uppermost tissues. So that the principle of suction here comes in play to pump up the materials of the soil into the body of the plant.

In germination, the food of the plant is furnished by the albumen of the seed, or by the gorged cotyledons of the embryo itself, as in peas and beans. This food is changed from the insoluble to the soluble state by the action of warmth and moisture; is dissolved, and, by capillary and osmotic action, is carried into the radicle, and used by the growing cells in the development of the plumule and the roots. By the time this supply is exhausted, the growing plantlet is able to live upon material furnished by the soil. Its first food is the starch, and other substances stored up in the seed the year before, and is organic matter. But the substances taken from the soil, dissolved in water, are carbonic acid, ammonia, and earthy and alkaline salts—mineral matters which cannot serve in building up the plant's fabric; these

are changed from the mineral to the organic state by the plant itself.

The root, then, is an important organ of absorption. Its cellular extremities are very permeable, and the water of the soil tends to penetrate them. By the various agencies just explained, it rises, through the cells and ducts, to the top of the plant, and escapes into the air by way of the leaves. Plants are said to absorb carbonic acid, ammonia, and sometimes vapor of water, directly from the air by their leaves, but the point is not well established.

EXERCISE LXXVI.

Evaporation and Digestion.

When the water of rains and dews, with the materials it has dissolved from air and earth, enters the plant, it takes the name of *ascending sap*. It thickens a little as it rises, by dissolving substances contained in the cells, and, on reaching the leaves, it undergoes various changes, and a large portion of its water escapes into the air by evaporation. The rapidity of its exhalation depends upon sunshine, the warmth and dryness of the air, and the structure of the leaves. A sunflower, with five thousand six hundred and sixteen inches of leaf-surface, was found, by experiment, to exhale from twenty to thirty ounces in a day, while it lost only three ounces in a warm, dry night, and none at all on a dewy night. A vine with twelve square feet of evaporating surface ex-

haled five or six ounces a day; and a young apple-tree, with eleven square feet of foliage, lost nine ounces a day. Hales calculated that the force which impels the sap in a vine in summer-time is five times as great as that which drives the blood through the large arteries of a horse; but the rate of evaporation has a large share in determining the force of the flow.

The influence of evaporation in starting the flow of sap is seen when a plant, with a certain time of leafing, is grafted upon a stock which puts forth its own foliage at a later period. The sap starts with the expansion of the leaves upon the grafted stem, and, of course, earlier than usual. Again, when the branches of a tree are enclosed and warmed in winter, so that the buds swell, the sap of the trunk is set in motion to supply the demand.

It is chiefly through the stomata that evaporation takes place. Situated in the epidermis, directly over the intercellular spaces, they permit the process when water is abundant, and arrest it when the supply fails. Their agency is of the utmost importance, for, unless the surplus water of the ascending sap is got rid of, the plant cannot digest its food; and, unless the action of the sun and air is checked when the supply is limited, it would wither and perish. In dry weather, from lack of moisture, the stomata shorten, straighten, and so close the orifice, and put a stop to evaporation; but, when full of water, they lengthen, curve outward, and open a free passage for the escape of the abundant moisture.

In some plants, as the cactus, the skin is so thick and dense that, succulent as they are, they yet live and flourish in dry, hot climates.

As we have before stated, the various inorganic substances, taken from the soil by the roots, and from the air by the leaves, are the food of plants. In the leaf-cells they undergo remarkable and very complex changes, some of which are understood, while others are not, and which it is the proper business of chemistry to explain. The most important action of the leaf is the reduction of carbonic-acid gas, ammonia, and water, to their elements, which are used for the formation of organic compounds. This may be regarded as the first step in the process of organization, and it takes place in the leaf only under the influence of light. Light is the motive power of the vegetable kingdom, and the countless myriads of expanded leaves are all little machines, upon which it takes effect. Light impels the actions of a leaf as falling water impels a water-wheel. The light is an active force, which is expended upon the leaf, is absorbed, and produces chemical decompositions. Carbon, the substance of charcoal, is thus separated from carbonic acid, and is ready to be used in the production of organic compounds, of which it is a universal constituent. The decomposition of water and ammonia gives also hydrogen and nitrogen, and these, with oxygen, form the chief bulk of all organized substances.

Animals have no such power of creating the organic substances which compose them. So that the whole animal world, and the entire vegetable kingdom, may be said to have their origin in leaves. But it is only the first step that is here taken. After carbonic acid, water, and ammonia, are decomposed, their elements are recombined in new groups under the constructive agency of the plant, and their sub-

sequent transformations may go on in all parts of the living structure to which the substances are conveyed by circulation. It is only in daylight that the initial step is taken in the green leaf; but at all times, by night as well as by day, the internal elaborations and the growth of parts may go on.

From this it will be seen that, so far as the air is concerned, plants and animals perform opposite offices. The lung and the leaf antagonize each other. Animals absorb oxygen from the air, and return carbonic acid to it; and, as carbonic acid is a poison, if there were no plants in the world, animals would, in sufficient time, contaminate it so that it would be unfit to breathe. But the poisonous exhalations of animals are absorbed by leaves, and destroyed, so that the entire vegetable kingdom acts as a vast purifier of the air.

You may very easily observe the powerful influence which light exerts upon plants. Remove a sprouting potato from the dark cellar into the sunshine; its pale, watery shoots will quickly begin to turn green. The first effect of light is thus to produce chlorophyll, and this chlorophyll becomes the medium of subsequent changes. Observe whether it is the upper or under surface of leaves which is exposed to the light. Whichever it be, reverse it, and note whether the leaf resumes its former position. Place a movable plant—one growing in a box or pot—with an erect stem, in a window, where the sunshine will fall upon it. After a little time observe the attitude of the stem. If you find it bent over toward the light, turn it round, and see if it will bend back again.

EXERCISE LXXVII.

The Circulation of Plants.

Although the movement of sap is not, like the flow of blood in animals, along a definitely traceable system of vessels, yet, in the larger plants, experiments show that it passes upward by one route and downward by another. In woody dicotyledons, the *crude*, or *ascending sap*, rises inside the cambium, and chiefly through the woody bundles of the outer circles of wood, hence called *sap-wood*, the inner portion of the tree, or heart-wood, having become so solid as to obstruct its passage. You may find proof of this in many ways. If you remove a ring of sap-wood from the stem of a tree, its branches wither and die, while hollow trees may flourish, and carry on all the processes of life. If you observe trees that have been cut down in spring, you can easily see in what portions the sap is most abundant. This crude sap may be obtained in spring, by making incisions into the sap-wood, from which it will trickle, or sometimes even flow in streams. It is nearly colorless, and tastes of the substances it has dissolved from the tissues of the tree. In monocotyledons, the rising sap has a much freer and wider course along the scattered bundles of fibro-vascular tissue.

The *elaborated*, or *descending sap*, passes along the inner layers of the bark, and furnishes the cambium with material for the growth of cells, and nourishment for the young buds in the axils of the leaves. You may stop its descent by removing a ring of bark from the stem or branch of a tree or shrub, but no wood will be formed below the mutilation. The

ringing of fruit-trees is one of the means of increasing the product of fruit above the ring. The formation of potatoes may be prevented by *ringing* the cortical layers of the stem. Tie a band tightly around the bark of a young branch. After a little time the branch swells, and forms a cushion above the ligature, while, below, it preserves its former size. When bark is accidentally rubbed off, the new growth, by which the place is gradually covered, comes from above. In monocotyledons, the elaborated sap descends along the fibres of the liber of each of the woody bundles, and in this way furnishes the cambium with nourishing materials.

In brief, then, water, containing the dissolved food of plants, is absorbed by the extremities of the roots. It rises through the latest-formed wood to the cellular tissue of the leaves, and is there submitted to the action of air and light. Changed to elaborated sap, it descends by the inner layers of the bark, yielding up, in its course, nutritious material to nourish all parts of the plant, till it reaches the root, from which it started.

Such is the course of the circulation in spring, when the leaves are young and active. Later in the season, as the woody tissues are more hardened, the sap rises in the cellular tissue. In autumn, the leaves are obstructed by the deposits of mineral matter, so that sap cannot flow in them; they dry up, and fall, evaporation ceases, and, with it, the movement of the sap. The so-called spongioles, however, continue to act, and so the tree is gorged with liquid before the winter sets in. This liquid dissolves the various peculiar matters deposited in the cells of the plant, and

is ready to flow in spring, when the tree is tapped. As the sap flows from the trunk, the supply is kept up by the action of the roots.

EXERCISE LXXVIII.

The Reproduction of Plants.

The processes described in the preceding exercises of this chapter are only concerned in the growth of the plant. As they are carried on by the root, stem, and leaves, these parts are known as the organs of growth, or *vegetative organs*. But the last and crowning act in the life of the plant is the production of seed, and in this process the flower is the portion immediately concerned. Flowers are hence called the *organs of reproduction*. The influence of pollen upon the pistil of a flower is called *fertilization*.

Except in rare instances, unless the ovules of a plant are acted upon by pollen, seeds do not appear. This is proved both by observation and experiment. You may prevent the production of seed by cutting away the stigma of the flower before the ripening of the pollen. In the case of ♀ flowers there is no seed, unless they are accessible to the pollen of ♂ flowers. A ♀ palm-tree, growing in a green-house at Berlin, for twenty-four years had not borne seed; but when some pollen, sent from a distance by mail, was artificially supplied to the stigmas of the tree, for the first time it bore fruit. Again, for eighteen years it was sterile, and in the same way it

was again fertilized by pollen, sent through the post. The date is a diœcious tree, upon which the Eastern countries depend for food. They suspend panicles of ♂ flowers near the single ♀ ones, to insure a crop of the fruit. One of the ways in which these people make war is, to destroy the ♂ date-trees; the ♀ ones are, of course, barren, and famine ensues.

The usual time of fertilization is when the flower is most perfect in its colors and fragrance. In the course of Nature there are many ways in which the pollen reaches the stigma. Either the stamens are longest, and it falls upon the stigma below, or, if shortest, the flower droops, as in the fuschia, and then, also, the pollen falls upon the stigma, or it may be thrown upon the stigma by spontaneous jerks of the stamen, or the anthers burst with violence, and so produce the same result. Pollen is also wafted by the winds from flower to flower, or conveyed by insects in their explorations for honey. In such plants as orchids, where the pollen is in masses, self-fertilization is impossible; the pistil can be acted upon only by pollen brought to it from other plants. By these various means pollen of all sorts is distributed upon all sorts of flowers, but only that of the same, or of nearly-related species, takes effect.

You know the structure of pollen-grains, and that the stigma is a mass of moist, cellular tissue, without epidermis. Landed upon this conductive tissue, the pollen-cell absorbs moisture, and its elastic intine swells, and pushes through the openings, or thin places of the more rigid extine, protruding a sort of tube, which grows downward, into the spongy centre of the style, till it reaches the ovary. Here it is met

by the ovules, and comes in contact with the nucleus, through the opening in the coats, at the apex of the ovule (the micropyle). Afterward the embryo appears, just within the micropyle, with its radicle pointing to the orifice. Before fertilization takes place, the ovule prepares for it by the formation, at the summit of the nucleus, of a special cell, called the *embryo-sac*, within which the embryo is formed. It is supposed that the contents of the pollen-grain pass into the embryo-sac by osmotic action. In the case of cone-bearing trees, the scales turn back, and expose their inner surface at the time when the air is filled with the pollen from the ♂ catkins, which is thus enabled to act directly upon the naked ovules. Then the scales close down, and remain till the seeds are ripe, after which they again open, and thus permit the seeds to escape. If you make sections of a pistil—when the pollen is in perfection—with a microscope, you may see these things for yourself. The spectacle of a pollen-covered stigma is one of great beauty and interest, even with a good magnifying-glass. After fertilization, the flower withers, and the vigor of the plant is spent in the growth and perfection of the fruit.

Reproduction of Ferns.—All over the lower surface of the prothallus (Fig. 352), cellular, pimple-like bodies are formed. These projections consist of four tiers of cells, with a canal running down the centre. They project below the lower surface of the prothallus, and, when mature, have an open mouth. The canal leads to a basal cell (embryo-sac). These bodies are the pistillidia or archegonia of ferns.

Antheridia.—These also are cellular projections,

formed on the under surface of the prothallus, but most abundantly near the centre, among the rootlets (Fig. 352). They are composed of one or two cells, developed from the lower face of one of the cells of the prothallus. Within these cells another is formed, in which soon appear a number of minute vesicles, called *sperm-cells*. When mature, the top of this antheridial cell falls off, like a lid, and the sperm-cells escape. Each of these, when ejected from the antheridium, emits an *anthrozoid*, a minute, ciliated body, which has the power of spontaneous movement (Fig. 414). It is by the passage of these antherozoids down the canal of the pistillidia that the corpuscle of the embryo-sac is fertilized. From the embryo thus produced, the young fern is developed, which, at maturity, produces sporanges and spores.

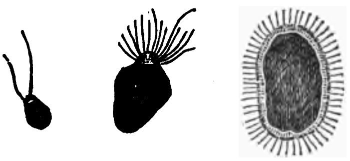
EXERCISE LXXIX.

The Movements of Plants.

It is usually considered that one of the prime distinctions between animals and plants is, that the former have the power of spontaneous motion, while the latter do not. But plants do manifest this faculty in various ways, and in a quite remarkable degree. It is seen in the very simplest forms of plant-life. These are the Algæ, the lowest class in the vegetable kingdom, to which sea-weeds and fresh-water confervæ belong. The mode of reproduction of the algæ is obscure; but, in certain fresh-water kinds, it takes

place by what are called "zoöspores," and which are represented in Fig. 414. It appears, from the latest examinations, that these zoöspores, which are of extreme minuteness, are of ovoid shape, and are partially or wholly covered with those extremely fine, hair-like

FIG. 414.



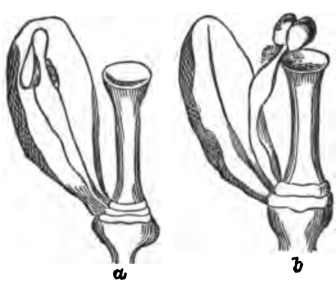
bodies, known as *cilia*, which have the power of spontaneously vibrating, or lashing backward and forward. They exist upon the surface of animal membranes, and, by their rapid, incessant, whipping motion, they cause the agitation and circulation of fluids upon such surfaces. Now, as soon as these minute zoöspores free themselves from the parent-cell, the cilia begin to vibrate with great rapidity, the vibrations being accompanied by a movement of rotation of the cell, and the result is a quick motion of the body through the water, similar to the movements of the lower forms of animal life. After the motion has continued from half an hour to several hours, the zoöspores settle down, lose their cilia, and give rise, by cell-division, to new organisms, resembling the parent. (Some algæ have a peculiar undulatory motion, hence they are called *oscillatoria*.)

In the case of higher plants, there are many capable of peculiar motions, some of which seem to re-

When the surface is touched, the leaf suddenly closes, like a steel-trap, and, if the intruding substance be an insect, it is immediately imprisoned, as shown in the figure. If nothing is caught, the trap soon reopens of itself, but, if there is a victim, it is held with considerable force.

This irritability, or sensitiveness, seen in leaves, is not uncommon, also, in the flower. Spontaneous motions occur in the petals of the sundew, and in the lip of the corolla of several of the Orchis tribe. It occurs in the organs of reproduction, and is then connected with the process of fertilization of the ovule. The stamens of the various species of barberry exhibit this irritability to a remarkable degree. If touched with a pin, or other object, at the base of the inside filament, the stamen will spring violently forward from its place within the petal, so as to bring the anther in contact with the stigma. In Fig. 418

FIG. 418.



the first position is shown at *a*, and the second at *b*. After a time the stamen slowly resumes its position. It might seem as if this arrangement were designed

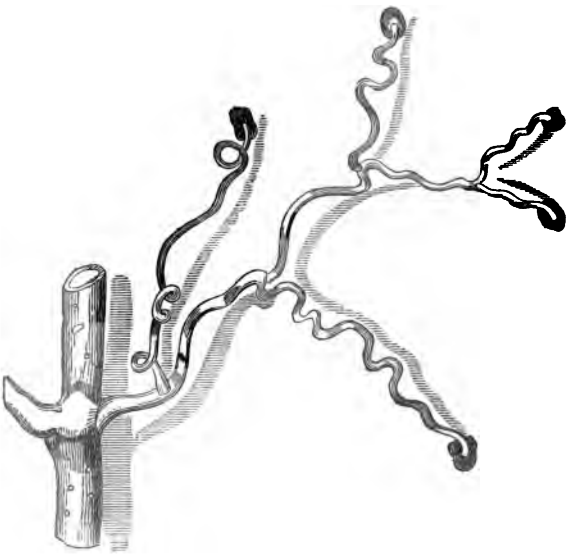
to secure the fertilization of the pistil from the pollen of its own flower. But this is not so. The movement takes place when an insect, in quest of the honey in the glands at the base of the pistil, touches the inside of one of the stamens. The pollen is thus thrown on the insect, which conveys it to the next flower it visits, and, leaving some of it on the stigma, brings about cross-fertilization.

Interesting motions, dependent upon contact, are also seen in the tendrils of many climbing plants, which bend and alter the position at the touch.

Climbing Plants.—These are of various kinds, and are so common as to be easily found by anybody who will look out for them. When a plant is seen to belong to this class, the first question, to be considered is, How does it climb upon its support? Does it twist around it (twining)? Does it put out fingers, roots, or suckers, for attachment (root-climbers)? or does it shoot out tendrils (tendril-climbers)? The tendrils of climbing plants exhibit interesting motions, dependent upon contact. They bend, and alter their position at the touch. This curling effect, which ensues from contact, is represented in Fig. 419. The motion consequent on a single touch increases for a time, then ceases, and, after a few hours, the tendril uncurls, and resumes its former position. Tendrils have a tendency to curl round any object with which they come into contact, except other tendrils of the same plant. It has been remarked as curious that, in some exceedingly sensitive plants, the falling of drops of rain on the tendril produces no movement. Tendrils are contrivances for climbing; they stretch out in search of support, and move through circuits to

find points of attachment. When one has secured a hold, it shortens by curling up so as to draw the main

FIG. 419.

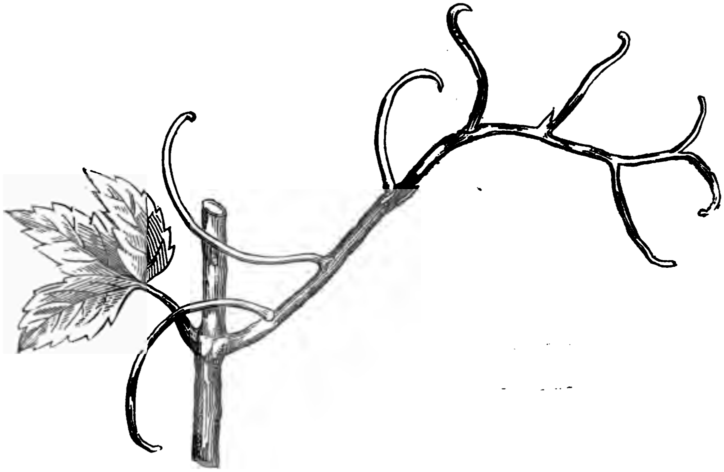


stem nearer to its support, then it rapidly becomes thicker and stronger than before.

Tendrils of the bigonia (Fig. 420) are described by Mr. Darwin as having a revolving movement, and, when they grow through a branch, and come into contact with the twig, the points bend in like claws, and the tendril holds on to the twig exactly like a bird when perched. The same naturalist says that the tendrils of this plant will slowly travel over the surface of a piece of wood, and, when the point, or "toe," of one of them finds a hole or crack, it inserts

itself, and it will sometimes, after many hours, withdraw from one fissure, as if it did not find it satisfactory, and seek another. There is something won-

FIG. 420.



derfully like instinct in all this. Prof. Gray remarks: "If we watch the tender passion-flowers which show the revolving so well on a sultry day, we may see with wonder that, when a tendril, sweeping horizontally, comes round so that its base nears the parent-stem, rising above it, it stops short, *rises stiffly upright, moves on in this position until it passes by the stem, then rapidly comes down again to the horizontal position*, and moves on so until it again approaches and again avoids the impending obstacle."

Observe the structure and watch the movements of tendrils in pumpkin, squash, gourd, and grape

vines. When a tendril has effected an attachment, and both ends are fast, how does it continue to coil? How do the tendrils of grape-vines move in respect to the light? In what way do they seize the support? In what way do the tendrils of the Virginia creeper and ivy attach themselves to walls? On a sultry day rub gently, with a stick or with the finger, the whole length of a vigorous tendril, and note the effect, and the time in which it is produced.

TWINERS.—Some plants rise by twisting around their support, as in the familiar case of the bean, or the hop, or the morning-glory. The extremity of the stem of a bean, which has grown a foot or two beyond its support, will extend from it in a nearly horizontal direction. If its position at a certain time be noticed, and then, if it be observed again some time afterward, it will be found to have changed place, and to point successively in different directions. The end of the stem thus revolves in a circle round its support, and the same kind of plant always turns in the same direction, although some go with the sun and some against it. The twining is, of course, the simple result of revolving in a circle, for, if the stem reaches away, and is arrested at any point by an obstacle, the portion beyond continues to move round in the same direction, and, as it lengthens, it of course twines around the impediment.

Observe the attitude of a stem of the bean, hop, or morning-glory, that overtops its supports. Mark the position, and observe it again in an hour or two afterward. What is the direction taken in each case? How does temperature affect the result? Do they move in the night? Make dots with ink along

the upper side of the outstretched stem, and see if the dots continue in that position.

Make a circuit of the garden and grounds in the daytime, and note the appearance and position of the leaves of each of the plants you encounter. Observe the attitude of the petiole and the blade, and the degree of flattening that the leaf exhibits. Note, also, the state of the floral organs. Observe them again in the evening, or at nightfall. Flowers that were open by day, and are now closed, should be observed again on the following day, to see if they reopen. If they do, watch them, and discover their times of opening and closing. If they do not, discover, if you can, how long they remain open.

Have the leaves of any of the species observed in the daytime assumed a different position?

When certain movements of leaves and petals, as curvature or folding, take place at particular times, and the new position is retained for a certain period, such movements are called the sleep of plants.

CHAPTER XX.

COLLECTING AND PRESERVING PLANTS.

EXERCISE LXXX.

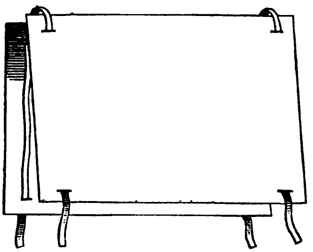
How to gather, press, and mount Plants.

FIG. 421.

IMPLEMENTS.—For your botanical excursions you will need a small trowel for digging roots (Fig. 421), or a large, strong, clasp-knife, that will serve both for digging and for cutting branches; a strong portfolio, from sixteen to twenty inches long, and ten or twelve inches wide, tied with tape or a strong cord. It should be made of two stout sheets of pasteboard, separated at the back (Fig. 422), and will be all the better if covered with enamelled cloth, to protect it from

moisture. This portfolio should contain a stock of thin, unsized paper, such as the poorest printing-paper, or grocer's tea-paper, and a close tin box, for preserving specimens, to be examined at home while fresh. Such a box is shown strapped upon the col-

FIG. 422.



lector, in Fig. 421. It shuts close, and has two compartments: the large one, with a door in the side, nearly as long as the box; and a small one, two or three inches deep, with a door in the end, for receiving small, delicate specimens of any kind.

WHAT TO GET.—Specimens that are intended for preservation must be gathered with great care, and pains must be taken to get average examples of each species. If possible, they should be gathered in dry weather. Herbs should be gathered when in flower and in fruit. They should be taken by the root, and, if it is not too large, this should be pressed, along with the rest, to show whether the plant is annual, biennial, or perennial. Thick roots, bulbs, tubers, and the like, should be thinned with a knife, or cut in slices, lengthwise. Buds and fruit should be obtained, as well as the expanded flower. All three may sometimes be found upon the same plant, but

generally they will have to be obtained at different times, unless, indeed, you are able to find buds, flowers, and fruit, all at once, upon plants in different stages of development.

Small herbs may be preserved entire. If the radicle leaves are withered at flowering-time, get a younger specimen in which they are fresh. When herbs arê too large for this, they may be cut in sections, or folded, or you must be content with branches and specimen-leaves taken from near the root. In the case of woody plants, one or more shoots should be taken, bearing leaves, flowers, and fruit. Both sterile and fertile flowers should be obtained from monœcious and diœcious plants.

Transporting.—The specimens, when freshly gathered, should be laid between the sheets of the portfolio, the more delicate ones being carefully placed between sheets of drying-paper, so that, on reaching home, they can be transferred to the press without being disturbed. The folds and doublings of leaves and petals of ordinary plants, occasioned by the wind, in the open field, are easily smoothed out when putting the plants in press.

Pressing.—As good an arrangement as any for pressing plants consists of two stout boards, that will not warp or bend, between which the specimens are placed, with any convenient weight—as stones, or masses of iron, of not less than fifty or sixty pounds—laid on the top. Between the plants you put layers of drying-paper. Newspapers answer very well for this purpose. They should be made into packets of about a dozen thicknesses, stitched together. Lay the plants smoothly between these packets. Put

unsized paper between the parts of a specimen that overlap each other, to prevent moulding, and hasten drying. Be careful to dispose the plants so that they will not lie directly above each other; keep the top of the pile as level as possible, to equalize the pressure. The number of packets interposed will depend upon the juiciness of the plants, and must be left to your own judgment. When plants are first put in press, the papers should be changed once a day for three or four days, after which every other day will answer. When the drying packets are changed, they should not be left lying upon the floor, but should be dried upon a line stretched across the room, or in the open air.

MOUNTING OF SPECIMENS.—When the plants are dry, the next thing is to mount them. For this purpose you will need—1. Strong, heavy, white paper, larger than foolscap—sheets 17½ inches in length by 11½ inches in width, is a size, on many accounts, desirable; 2. Corrosive sublimate, for poisoning plants, to keep off insects; 3. Glue, to fasten them upon the paper.

Dissolve about an ounce of sublimate in a quart of alcohol. It should be labelled, and kept with great care, as it is very poisonous. A simple way of applying the solution is to pour a little into a large, flat platter, so as to cover the bottom, and "immerse the whole specimen for a second therein." After poisoning, the specimens are to be laid between driers, and subjected to slight pressure for twenty-four hours, when they are ready to be fastened to the paper. The flowers and tender parts of coarse, tough plants are all that need poisoning.

The specimens are to be fastened to the paper with hot glue, about as thick as cream, laid on to the plants with a camel's-hair pencil. Strips of thin, gummed paper should then be fastened over the thicker parts, to prevent their coming loose in handling. Prepare your glue in an earthen or porcelain-lined vessel, as corrosive sublimate acts on all common metals, and the brush, passing from plant to glue again and again, will be likely to produce stains if there is a trace of metal in the solution.

EXERCISE LXXXI.

Labelling and arranging Plants.

In some methods of studying botany the scientific name of a plant is the first thing inquired for. But here you have reached the last exercise of the book, and have prepared a collection of plants for receiving labels, while yet ignorant of this part of the subject. It was, however, not the design of the present work to teach you to label plants, with their scientific names, for these are arrived at only by the study of the groups known as genera and species, and they are far too numerous, and are based upon too many combinations of detail in structure, to make it possible to deal with them in a text-book like this. Besides, in the true order of study, naming follows, and depends upon classification. You have already done something in this direction. You know the characters upon which classes are founded, have studied a

few natural orders, and have begun to consider the affinities of plants. Now, classification, from beginning to end, consists in associating plants by these affinities, and can be rationally performed only when they are perceived. The reason for a plant's scientific name is found in its predominating affinities. Intelligently to label your plant, therefore, you should be so familiar with its assemblage of characters and relations to other plants, that you can see why it is placed *here*, and not *there*, in the established arrangement.

The work you have begun now requires a regular botanical manual to carry it out. There are various books that may be used for this purpose, but Gray's "Manual of the Botany of the Northern United States" may be commended as a most excellent work for the purpose. It gives a full statement of the characters of each order, followed by a description of the genera it contains, and then the peculiarities of the species of each genus are fully given, so that a plant is easily identified. The genus and species determine the scientific name. When you have had some experience in tracing the ordinal, generic, and specific characters of plants, you will read, with profit and pleasure, the chapter of the "Manual" upon classification, and be prepared fully to understand the system by which plants are named.

AN EXPLANATION OF THE ABBREVIATIONS USED IN THE BOTANICAL CHARTS.

Seven principal references are made with a Capital Letter, to be looked for below *each Illustration; and the subordinate parts are* then *noted by small letters. A reference within a* ○ *implies* not magnified; (*on the left indicates a Longitudinal Section, and* ⌒ *above, a Transverse.*

L.	Leaf.
— p.	petiole.
— l.	limb.
— l. l. ..	leaflet.
— s.	stipule.

I. fl.	Inflorescence (in flower).
I. fr.	Infructescence (in fruit).
– p.	peduncle.
– p. p.	pedicel.
– b.	bract.
– b. g.	glume.
– b. p.	pale.
– g. r.	general receptacle.

Æ......	Æstivation (diagram).
green...	sepals.
red.....	petals.
yellow..	stamens.
brown..	carpels.
blue....	ovules.
shaded..	adhesion of *whorls*.

Fl.......	Flower.
— f. r. ..	floral receptacle.
— ph....	perianth.
— ph. l..	leaves of.
— ca	calyx.
— ca. s. .	sepals.
— co. ...	corolla.
— co. p .	petals.
— s.	stamen.
— s. f. ..	filament.
— s. a...	anther.
— s: c. ..	connective.
— s. p. ..	pollen.
— pi. ...	pistil.
— pi. ca .	carpel.
— o.	ovary.
— o. cl. .	cell of.
— o. d. .	dissepiment.
— o. pl..	placenta.
— o. f...	funicular cord.
— sty. ..	style.
— sti. ...	stigma.
— oo. ...	ovule.
— oo. rh.	raphe.

Fl. oo. ch.	chalaze.
— oo. f. .	foramen.
— n.	nectary.

Fr.	Fruit.
— pe	pericarp.
ep.. . .	epicarp.
me. . .	mesocarp.
en. . .	endocarp.
— ca..	carpel.
— pe. v.	valve.
— pe. cl.	cell.
— pe. d.	dissepiment.
— pe. p.	placenta.
— pe. f.	funicular cord.
— pe. f. a. . . .	arillus.

S.	Seed.
— in.	integument.
ts. . . .	testa.
tg.. . .	tegmen.
— h.	hile.
— m. . . .	mycropyle.
— rh. . . .	raphe.
— ch	chalaze.
— ar. . . .	arillode.
— al.	albumen.

E.	Embryo.
— ca.	caulicle.
— co. . . .	cotyledon.
— r.	radicle.
— pl. . . .	plumule.

GLOSSARY.

AC'CESSORY, or ANTHOCAR'POUS FRUITS. Those formed by the union of many separate flowers.

ACCUM'BENT COTYLE'DONS. Having the radicle folded against their edges.

ACHE'NIUM. A small, indehiscent pericarp.

ACHLAMYD'EOUS. Having no protective organs.

AC'ROGENS. End-growers.

ADHE'SION. The growing together of different floral whorls.

AD'NATE, or DORSIFIXED (anther). With the filament running up the back of the anther.

ÆSTIVA'TION, or PRÆFLORA'TION. The process of flowering.

—— ——, *Val'vular*. When the edges of the sepals and petals just meet, without overlapping.

—— ——, *Indu'plicate*. Where the edges of the sepals or petals are turned slightly inward, or touch by their external face.

—— ——, *Redu'plicate*. When the edges are turned slightly outward, or touch by their internal face.

—— ——, *Contorted*. When each leaf overlaps its neighbor, and the parts seem twisted together.

—— ——, *Con'volute*. When each sepal or petal wholly covers those within it.

—— ——, *Im'bricate*. When the petals or sepals overlap one another like shingles on a roof.

—— ——, *Vex'illary*. When the external petal, as in a vexillum, is largest and folds over the other petals.

ÆSTIVA'TION, or PRÆFLORA'TION, *Coch'lear*. When one of the petals of the corolla, hollowed like a spoon, covers the other petals.

—— ——, *Supervolúte*. When the petals are all folded around in one direction inwrapping one another.

ANAT'ROPOUS (ovule). Turned over, so as to bring the mycropyle to the hilum.

ANDRÆ'CIUM. All the stamens of a flower taken together.

AN'GIOSPERM. A plant having its seeds enclosed in a pericarp.

AN'NUAL. Living one year.

AN'NULAR. In rings.

AN'NULUS. A ring.

AFFIN'ITY. The resemblance of character among plants.

AG'GREGATE (flower). Composed of florets united within a common receptacle.

ALBU'MEN (of seeds). The tissue in which the embryo is embedded, and by which it is nourished.

AL'GA (pl., *Algæ*). Sea-weeds and other cryptogamous water-plants.

AN'OPHYTES. Cryptogamous plants.

ANTHER. The thickened, oblong head of a filament.

ANTHERID'IA, or AN'THERIDS. Organs in cryptogamous plants, answering to the anthers of flowering plants.

APOCAR'POUS. Having the carpels separate.

APPENDIC'ULAR (connective). Extending above or below the anther, and taking the form of a feather, a fleshy mass, etc.

ARACH'NOID. Resembling a cobweb.

ARCHEGO'NIUM, or ARCH'EGONE. The same as pistillidia.

ASCENDING OVULES. Rising upward obliquely.

AWN. The beard of oats, barley, etc.

AXIAL EM'BRYO. Situated in the centre of the albumen.

AXILE. Belonging to the centre, or axis.

AX'ILLARY. Starting from the axil of a leaf.

BA'SAL. Situated at the base.

BA'SIFIXED. Same as innate.

BERRY. A thin-skinned, indehiscent, juicy fruit, having the seeds embedded in a pulpy mass.

BIDEN'TATE, or BICUS'PID. Two-toothed.

BIEN'NIAL. Living two years.

BI'NARY. Arranged in twos.

BLADE. The flattened green part of a leaf.

BORAGINA'CEÆ. Plants of the Borage family.

BRACT. A small leaf or scale, from the axil of which a flower, or its pedicel, proceeds.

CADU'COUS (floral whorls). Falling when the flower opens.

CALYP'TRA. The cap or hood of a sporange.

CALYX. The outer covering of a flower.

CAM'BIUM. A glutinous sap occurring between the newest layers of wood and bark.

CAMPYLOT'ROPOUS (ovule). Having the apex bent over close to the base.

CAP'ILLARY. Pertaining to capillary or very minute tubes.

CAP'SULE. The pod of a compound pistil; the dry, dehiscent fruit of syncarpous pistils.

CAR'PEL. A simple pistil, or one of the parts of a compound pistil.

CARYOP'SIS. A one-celled, one-seeded fruit with pericarp, membranous, and united to the seed.

CELL. A small chamber: the ultimate form in plant physiology.

CELLULAR TISSUE. The mass of substances formed by the union of cells.

—— ——, *Regular*. Having cubical cells.

—— ——, *Prismatic*. Having elongated cells.

—— ——, *Tabular*. Having flattened cells.

CELLULAR TISSUE, *Muriform*. Having the cells arranged like courses of brick in a wall.

CHALA'ZA. The place where the nucleus and the coats of an ovule grow together.

CHARACTERS OF PLANTS. The permanent features of species.

CHLO'ROPHYLL. The green coloring-matter of plants.

CIL'IUM (pl., CILIA). A vibrating hair or lash.

COCH'LEAR ÆSTIVATION. (*See* ÆSTIVATION.)

COHE'RENT. Growing together. Said of identical parts. Thus petals with petals, sepals with sepals, etc.

COHE'SION. Growing together of parts of the same sort.

COLUM'NAR. Shaped like a column.

COM'MISSURE. The face by which two carpels cohere, as in Umbelliferæ.

COMPLETE (flower). One having all the organs.

COMPOS'ITÆ. Plants whose flowers are made up of several florets with syngeneseous stamens.

COMPOUND (pistil). Consisting of several united carpels.

CON'ICAL. Round, and decreasing to a point.

CONNEC'TIVE. A continuation of the filament which unites the two lobes of the anther.

CONNI'VANT. Converging.

CONTORTED ÆSTIVATION. (*See* ÆSTIVATION.)

COROL'LA. The inner covering of a flower.

COR'TICAL LAYER. A layer of bark.

CORYMB'. A species of inflorescence in which the lesser flower-stalks are produced along both sides of the common stalk, rising, however, to the same height as the latter. *Ex.*, scurvy-grass.

CREM'OCARP. The fruit of Umbelliferæ, consisting of two indehiscent carpels.

CRUCIF'ERÆ. Plants having a cruciform corolla; stamens four—two long, and two short; inflorescence racemose, without bracts.

CRYPTOG'AMOUS. Flowerless.

CULM. The stem of grasses and sedges.

CU'PULE. A little cup; the involucre of a nut.

CYME. A loose, irregular, definite inflorescence.

CYMO'SE, or DEFINITE INFLORES'CENCE.

CYP'SELA. An achenium with an adherent calyx-tube. *Ex.*, the Compositæ.

Decan'drous. Having ten stamens.

Decid'uous. Subject to fall off.

Decid'uous (floral whorls). Falling before the fruit is formed.

Decus'sated. Crossed. In the shape of an X.

Definite. Not exceeding the number 12.

Dehis'cence. A bursting open, as of a pod or of an anther.

Dehis'cent. Bursting open.

Diadel'phous. Having the filaments grown together in two bundles.

Dian'drous. Having two stamens.

Dichlamyd'eous. Having two protecting organs, viz., calyx and corolla.

Dichot'omous. Regularly dividing by pairs.

Dic'linous. Having the stamens and pistils in separate flowers.

Didyn'amous. Having two long and two short stamens.

Dilated. Spread; flattened out.

Dim'erous. Arranged in twos.

Dimid'iated (anther). Having one lobe abortive or suppressed

Diœ'cious. Having male flowers on one plant and female on another.

Dis'coid Flower-heads. Those destitute of ray-florets.

Disk Florets. The inner florets of a flower-head.

Dissep'iments. Partitions in an ovary or fruit.

Dist'ichous. Having two rows.

Distinct. Not held by *cohesion*.

Dodecan'drous. Having twelve stamens.

Dorsal. Belonging to the back.

Drupe. A pulpy, indehiscent, one-celled, one- or two-seeded fruit, with succulent or fibrous epicarp, and hard, stony, distinct endocarp (*ex.*, peach).

Ducts. Tubes lying among the cells of plants; called also *vessels*.

Dura'men. Heart-wood.

Emar'ginate (anther). Having the summit or base of its cell extending upward or downward, a little beyond the connective.

Endecan'drous. Having eleven stamens.

En'docarp. The inner coat of a fruit.

En'dogens. Inside-growing plants.

Ennean'drous. Having nine stamens.

Ep'icarp. The outer covering of a fruit.

Epider'mis. The cellular layer covering the external surface of plants.

Epig'ynous. Having the stamens inserted upon the ovary.

Epipet'alous. Having the stamens inserted upon the corolla.

Erect Ovules. Rising upright from the base of the cell.

Essential Organs (of flowers). Those requisite for the production of the seeds, that is, the stamens and pistil.

Etæ'rio. Same as *aggregate fruits*.

Exalbu'minous (seeds). Those without albumen.

Excen'tric Embryo. Situated away from the centre of the albumen.

Ex'ogens. Outside-growers.

Exsert'ed (stamens). Extending beyond the corolla.

Ex'tine. The outer coat of a pollen-grain.

Extro'rse. Facing outward.

Fas'cicle. A cymose cluster of nearly sessile flowers.

Fenes'trated. Having chinks or slits.

Fertile. Bearing seed.

Fi'bro-vas'cular. Pertaining to fibre, with vessels or ducts.

Fil'ament. The stem-like part of a stamen.

Fil'iform. Thread-like.

Florets. The flowers of a flower-head.

Free. Not held by *adhesion*.

Free-central Placentation. Having the ovules in the centre of the pistil, without dissepiments.

Frond. The leaf of a fern.

Fun'gus (pl., **Fungi**). A plant of the mushroom kind.

Gamopet'alous. Having the petals grown together.

Gamosep'alous. With sepals grown together.

Globo'se. Round, like a globe.

Glom'erule. A cymose cluster of sessile flowers in the axil of a leaf.

Gluma'ceæ. The grasses and sedges.

Glume. The floral covering of grasses and sedges.

Go'nophore. Supporting stamens and pistil.

Gramin'eæ. The grasses.

Gym'nosperm. A plant bearing naked seeds. *Ex.*, pine, hemlock.

Gynan'drous. Having the stamens consolidated with the pistil.

Gyn'obase. A dilated base, or receptacle, supporting a multilocular ovary.

GYN'OPHORE. The pedicel raising the pistil or ovary above the stamens.

HEPTAN'DROUS. Having seven stamens.

HERMAPH'RODITE. Containing both stamens and pistils.

HESPERID'IUM. A fruit of the orange kind.

HETEROG'AMOUS. Bearing flowers of different kinds, as regards the pistils and stamens.

HEXAN'DROUS. Having six stamens.

HI'LUM. The scar left on a seed after separation from the placenta.

HOMOG'AMOUS. Bearing flowers all of one kind as to the pistils and stamens.

HORIZON'TAL OVULES. Lying level with the horizon.

HYPOG'YNOUS. Having the stamens inserted under the ovary.

IM'BRICATE ÆSTIVATION. (*See* ÆSTIVATION.)

INCLUDED (stamens). Having their entire length within the corolla.

INCUM'BENT COTYLE'DONS Having the radicle folded back on one of them.

INDEFINITE. Exceeding the number 12.

INDEHIS'CENT. Not bursting the pod.

INDUPLICATE (valvate æstivation). *See* ÆSTIVATION.

INDU'SIUM. The scale or covering of a fruit-dot on the fern-leaf.

INFERIOR. Below.

INFLORES'CENCE. The arrangement of flowers on the stem.

IN'NATE, or BASIFIXED (anther). With the filament running straight into the base of the connective.

INSERTION. The attachment of an organ to its support.

IN'TERNODE. The space between two nodes.

IN'TINE. The inner coat of a pollen-grain.

INTRO'RSE. Facing inward.

INVOLU'CRE. The outer green circle of a flower-head.

IRREGULAR DEHIS'CENCE. When the seeds are discharged from the ovary through chinks or pores, or other irregular opening.

LACU'NÆ. A hole or gap in cellular tissue, produced by the destruction of cells.

LATERAL. Pertaining to the side.

LA'TEX. The milky sap contained in the stalks and leaves of certain plants.

LATICIF'EROUS VESSELS. Those containing the latex.

LEGU'ME. A pod dehiscent into two valves, leaving the seed attached at one suture.

LI'BER. The inner bark next the wood.

LICH'EN. The plant commonly called rock-moss, tree-moss.

LIMB. Border of a leaf, etc.

LIG'ULATE. Tongue-shaped.

LOBE. A large division of an organ.

LOCULICI'DAL DEHIS'CENCE. When the splitting of the ovary opens into the cells by the dorsal suture.

LO'MENT. An elongated pod with two valves which are divided transversely.

MALE (flowers). Having stamens, but no pistils.

MARCES'CENT (floral whorls). Persisting in a dry and withered state.

MEDUL'LARY RAYS. Rays extending from pith to bark in exogens.

MEDUL'LARY SHEATH. A thin layer of vascular tissue surrounding the pith.

MER'ICARP. One half of the fruit of an umbellifer.

MES'OCARP. The middle layer of a pericarp.

MI'CROPYLE. The opening into the coats of an ovule.

MIDRIB. The main rib of a leaf.

MONADEL'PHOUS. Having the filaments grown together in one bundle.

MONAN'DROUS. Having one stamen.

MONOCHLAMYD'EOUS. Having only one protecting organ, the calyx.

MONŒ'CIOUS. Having male and female flowers on the same plant.

MULTIPLE (pistil). Consisting of several distinct carpels.

MYCE'LIUM. The filamentous parts of a fungus, answering to root, stem, and leaves of higher plants.

NEC'TARY. A little gland on the claw of a petal, which secretes a sugary liquid.

NEUTRAL. Having neither stamens nor pistils.

NU'CLEUS. The centre of an ovule, where the embryo is formed.

NUT. A hard, one-seeded, indehiscent fruit.

OBLONG. Having greater length than width.

OBSOLETE. Not distinct; rudimental.

OCTAN'DROUS. Having eight stamens.

OPER'CULUM. The lid of a sporange.

ORGANOG'RAPHY. A description of the organs of plants.

ORTHOT'ROPOUS (ovule). Having its base in one position with that of the nucleus, while the mycropyle is at the apex.

OS'MOSE. The tendency of fluids to intermix.

O'VARY. Lowest part of the pistil, containing the seeds.

O'VOID. Resembling an egg.

O'VULE. A rudimentary seed.

PA'LEÆ. Chaff; the bract-like bodies growing among the florets of a flower-head.

PAN'ICLE. An open cluster.

PAP'PUS. The down, beard, bristles, etc., representing the calyx in Compositæ.

PAREN'CHYMA. Cellular tissue having a spheroidal, not tubular form.

——, *Complete*. When the cells lie close together, without intervals.

——, *Incomplete*. When there are unoccupied spaces between the cells.

PARAPHY'SES. Stalks or filaments accompanying the antheridia of mosses.

PARI'ETAL PLACENTA'TION. Having the placenta attached to the walls of the ovary.

PEDUN'CLE. The stem supporting the flower and fruit of a plant.

PENTAM'EROUS. Arranged in fives.

PENTAN'DROUS. Having five stamens.

PENTAS'TICHOUS. In five rows.

PE'PO. An indehiscent, fleshy fruit, with seeds borne on a parietal placenta, and with the epicarp more or less thick and hard. *Ex*., squash.

PEREN'NIAL. Living many years.

PERFECT (flowers). Having stamens and pistils.

PER'IANTH. The calyx of a single flower; the leaves of a flower when calyx and corolla are not readily distinguishable.

PER'IGONE. Same as perianth.

PERIG'YNOUS. Having the stamens inserted upon the ovary.

PER'ISTOME. A fringe of teeth around the mouth of a sporange.

PERSISTENT. Remaining beyond the usual period.

PERSISTENT (floral whorls). Remaining till the fruit is mature.

PET'AL. A lobe of the corolla.

PET'ALOID. Like a petal.

PET'IOLE. A leaf-stalk.

PHYLLOTAX'IS. Leaf arrangement.

PIL'EUS. A cap; the head of a fungus.

PIN'NA (pl., PINNÆ). One leaflet of a pinnate leaf, or branch of a compound pinnate leaf.

PIN'NULE. A subdivision of a pinna.

PIS'TILLATE. Having a pistil, but no stamens.

PISTILLID'IA, or PIS'TILLIDS. Organs in cryptogamous plants, answering to the pistils of flowering plants.

PLACEN'TA (pl., PLACENTÆ). That part of the ovary which bears the ovules.

PLU'MULE. The first bud of a young plant.

POL'LEN. The powder contained in the anther.

POLLIN'IA. Pollen-grains cohering in masses.

POLYADEL'PHOUS. Having the filaments grown together in three or more bundles.

POLYAN'DROUS. Having more than 12 stamens.

POLYCOTYLED'ONOUS. Having seed with two or more lobes.

POLYG'AMOUS. Having male, female, and hermaphrodite flowers on the same plant.

POLYHED'RIC. Many-sided.

POLYPET'ALOUS. Having the petals distinct.

POLYSEP'ALOUS. Having the sepals distinct.

POME. A fleshy, indehiscent, many-celled fruit, with tough endocarp, and enclosed by the calyx-tube. *Ex*., apple.

PO'ROUS. Having pores or holes.

PRÆFLORATION. (*See* ÆSTIVATION.)

PRI'MINE. The outer sac of an ovule.

PROSEN'CHYMA. Fibrous tissue having cells with tapering extremities.

PROTECTING ORGANS (of flowers). Those which cover and nourish the stamens and pistil.

PROTHAL'LIUM, or PROTHALLUS. The leaf-like body into which the spore of a fern expands.

PRO'TOPLASM. A mucilaginous substance spread on the inside of cell-walls.

PUBES'CENT. Having fine, short hairs or down.

PYX'IS. A pod which dehisces by the falling off of a sort of lid.

QUI'NARY. Arranged in fives.

QUINCUN'CIAL PRÆFLORATION. (*See* PRÆFLORATION.)

RACE'ME. An elongated flower-cluster.

RA'CEMOSE. Growing in racemes.

RACH'IS. The axis of several kinds of inflorescence.

RANUNCULA'CEÆ. Belonging to the Ranunculus order.

RANUN'CULUS. Buttercup.

RAY FLORETS. The outer petal-like florets of a flower-head.

RECEP'TACLE. The support of a flower.

REDUPLICATE ÆSTIVATION. (*See* ÆSTIVATION.)

REN'IFORM. Kidney-shaped.

REPRODUCTION, ORGANS OF. Those concerned in the production of the seed.

RETIC'ULATED. Resembling net-work.

RHA'PHE. The connection between the base of the nucleus and the base of the ovule.

RHAPH'IDES. Minute transparent crystals found in the tissues of plants.

SAMA'RA. A dry, indehiscent fruit, single or in pairs, with winged apex or margin.

SAP. The juice of plants.

SCOR'PIOID. Curved like the scorpion's tail.

SECUN'DINE. The inner sac of an ovule.

SEP'AL. A leaf, or part of the calyx.

SEPTICI'DAL DEHIS'CENCE. When the ovary splits through the partitions of the dissepiments.

SEPTIF'RAGAL DEHISCENCE. When the valves of the ovary fall away, leaving the dissepiments behind.

SES'SILE. Directly issuing from stem or stalk.

SE'TA. The stalk of a sporange.

SIG'MOID. Curved in two directions, like the letter S.

SI'LEX. Flint.

SIL'ICLE. A short, broad silique.

SIL'IQUE. An oblong pod with two sutures, and dissepiment between, having seeds on either side of the dissepiment.

SIMPLE (pistil). Consisting of only one carpel.

SOLITARY. Standing alone.

SORO'SIS. A kind of multiple fruit. *Ex.*, pineapple.

SO'RUS (pl., SO'RI). A cluster of fruit-dots on the fronds of ferns.

SPIKE. An elongated flower-cluster with sessile flowers.

SPIKELET. A small spike; the inflorescence of grasses.

SPINOUS. Thorny.

SPI'RAL. Winding like the thread of a screw.

SPON'GIOLES. The termination of a radicle.

SPORANGE. Same as spore-case.

SPORE. A grain in cryptogamous plants which performs the functions of a seed.

SPORE-CASE, or SPORA'NGE. Cells containing the spores of ferns.

SQUA'MULÆ, or LODICULE. Minute scales at the base of the ovary of grasses.

STAM'INATE. Having stamens, but no pistils.

STERILE. Not producing seed.

STIPE. A stalk.

STIP'ITATE. Having a stipe.

STIP'ULE. An appendage, like a leaf, situated at the base of a leaf or petiole.

STO'MA (pl., STOMA'TA). Breathing-pores of leaves and other organs.

STRI'ATED. Grooved or channelled.

STRO'BILUS. A kind of multiple fruit. *Ex.*, pine-cones.

STYLE. The stem of the pistil next above the ovary.

SUB'ULATE. Tapering like an awl.

SUPERVOLU'TE ÆSTIVATION. (*See* ÆSTIVATION.)

SUSPENDED OVULES. Hanging perpendicularly from the summit of the cell.

SU'TURE. The seam formed by the union of two margins in any part of a plant.

SYCO'NUS. A kind of multiple fruit. *Ex.*, fig.

SYMMET'RICAL. Having the number of its parts of each sort equal, as five sepals, five petals, and five stamens.

SYNCAR'POUS. Having the carpels connected.

SYNGENE'SIOUS. Having the anthers united.

TERMINAL. Belonging to the extremity.

TER'NARY. Arranged in threes.

TETAN'DROUS. Having four stamens.

TETRADYN'AMOUS. Having four stamens, two long and two short.

THA'LAMUS. The receptacle of the flower, or the part of the peduncle into which the floral organs are inserted.

THECA. A case.

TO'RUS. Same as Thalamus.

TRANSVERSE. Crosswise.

TRIAN'DROUS. Having three stamens.

TRI'MEROUS. Arranged in threes.

TRIS'TICHOUS. In three ranks.

TUBE'RCULATED. Pimpled.

UM'BEL. A flower-cluster having the flower-stalks spread moderately from a common point, forming a plane or convex surface above.

UMBELLIF'ERÆ. Plants blossoming in umbels.

U'TRICLE. A kind of achenium with thin, membranous pericarp, which is sometimes dehiscent.

VAG'INULE. The collar or sheath at the base of a sporange-stalk.

VALVE. One of the parts into which a pericarp or an anther splits.

VAL'VULAR. After the manner of a valve.

VAL'VULAR (or REGULAR) DEHIS'CENCE. When the ovary splits into regular pieces called valves.

VENA'TION. The manner in which the veins are arranged in a leaf.

VEN'TRAL. Belonging to the anterior part.

VERBENA'CEÆ. Plants of the Verbena family.

VE'RSATILE. Freely movable.

VER'TICAL. From top to bottom; lengthwise.

VEX'ILLARY ÆSTIVATION. (*See* ÆSTIVATION.)

VIL'LOUS (surface). Having very long, soft, erect, straight hairs.

VIT'TÆ. The oil-sacs in the fruit of the Umbelliferæ.

VOL'VA. The outer wrappage of the young mushroom.

WHORL. A ring of leaves, flowers, or other organs around a stem.

ZO'OSPORE. A spore of certain water-plants which moves by means of vibratile cilia.

APPENDIX.

ON THE EDUCATIONAL CLAIMS OF BOTANY.

The present method of dealing with the subject of botany is the outgrowth of a desire to gain certain advantages in general mental culture, which can be only obtained by making Nature a more direct and prominent object of study in primary education than is now done. I have thought it desirable to present the reasons which have led to its preparation more fully than would be suitable in an introduction, and therefore place them at the close of the work.

The subject of mind has various aspects; that in which the teacher is chiefly concerned is its aspect of *growth.* I propose to consider the subject from this point of view; to state, first, some of the essential conditions of mental unfolding; then to show in what respects the prevailing school culture fails to conform to them; and, lastly, to point out how the subject of Botany, when properly pursued, is eminently suited to develop those forms of mental activity, the neglect of which is now the fundamental deficiency of popular education.

Mind is a manifestation of life; and mental growth is dependent upon bodily growth. In fact, these operations not only proceed together, but are governed by the same laws. As body, however, is something more tangible and definite than mind, and as material changes are more easily apprehended than mental changes, it will be desirable to glance first at what takes place in the growth of the body.

I.—HOW THE BODY GROWS.

All living beings commence as germs. The germ is a little portion of matter that is uniform throughout, and is hence said to be *homogeneous.**

* In the following statement two or three words will occur with which

The beginning of growth is a change in the germ, by which it is separated into unlike parts. One portion becomes different from the rest, or is *differentiated* from it; and then it is itself still further changed or differentiated into more unlike parts. In this way, from the diffused uniform mass, various tissues, structures, and organs gradually arise, which, in the course of growth, constantly become more diverse, complex, and *heterogeneous*. But, accompanying these changes, there is also a tendency to *unity*. It is by the assimilation of like with like that differences arise. Nourishment is drawn in from without, and then each part attracts to itself the particles that are like itself. Bone material is incorporated with bone, and nerve material with nerve; so that each different part arises from the grouping together of similar constituents. This tendency to unity, by which each part is produced, and by which all the parts are wrought together into a mutually dependent whole, is termed *integration;* and the combined operations by which development is carried on constitute what is now known as *Evolution*.

At birth, bodily development has been carried so far that the infant is capable of leading an independent life. Mental growth commences when the little creature begins to be acted upon by *external agencies*. An already-growing mechanism takes on a new kind of action in new circumstances, and body and mind now grow together. The development of mind depends upon certain properties of nervous matter by which it is capable of receiving, retaining, and combining impressions. An organism has been thus prepared, upon which the surrounding universe takes effect, and the growth of mind consists in the development of an internal consciousness in correspondence to the external order of the world.

II.—HOW THE MIND GROWS.

At birth we say the infant *knows* nothing; that is, it recognizes *no thing*. Though the senses produce perfect impres-

---

some readers may be unfamiliar. But more precise thoughts require more precise terms to mark them; and, as these terms are now established, their use here is admissible as well as advantageous.

sions from the first, yet these impressions are not distinguished from each other. This vague, indefinite, homogeneous sensibility or feeling may be called the germ-state of mind. As bodily growth begins in a change of the material germ, so mental growth begins in a change of feeling. This change of feeling is due to a change of external impressions upon the infant organism. Were there no changes of impression upon us, there could never be changes of feeling within us, and *knowing* would be impossible. If, for example, there were never an alteration of temperature, and a resulting change of impressions upon the nerves, we should be forever prevented from knowing any thing of *heat*. The first dawn of intelligence consists in changes of feeling by which *differences* begin to be recognized. Mind commences in this perception of differences; it cannot be said that we know any thing *of itself*, but only the differences between it and other things. And, as in bodily growth, so in mental growth, there is an assimilation of like with like, or a process of *integration*. From the very first, along with the perception of difference, there has been also a perception of likeness. The clock-stroke, when first heard, is felt simply as an impression *differing* from others that precede and succeed it in the consciousness; but, when heard again, not only is there this recognition of difference, but it is perceived as *like* the clock-stroke which preceded it. This second impression is assimilated to the first, and, when a third arises, it also coalesces with the former like impressions. And so of all other sights, sounds, and touches. Under the influence of constant changes of impression, and a constant assimilation of like with like, there arise, at first vague, and then distinct unlikenesses among the feelings; that is, sights begin to be distinguished from sounds, and sounds from touches, while, at the same time, differences begin to be perceived among the impressions of each sense. In this way, the consciousness, at first homogeneous, grows into diversity, or becomes more *heterogeneous*, while its separated or differentiated parts are termed *ideas*.

Let us look into this a little more closely. When an infant opens its eyes for the first time upon the flame of a candle, for

example, an image is formed, an impression produced, and there is a change of feeling. But the flame is not known, because there is as yet no *idea*. The trace left by the first impression is so faint that, when the light is removed, it is not remembered; that is, it has not yet become a mental possession. As the light, however, flashes into its eyes a great many times in a few weeks, each new impression is added to the trace of former impressions left in the nervous matter, and thus the impression deepens, until it becomes so strong as to remain when the candle is withdrawn. The idea therefore grows by exactly the same process as a bone grows; that is, by the successive incorporation of like with like. By the integration of a long series of similar impressions, one portion of consciousness thus becomes differentiated from the rest, and there emerges the *idea* of the flame. Time and repetition are therefore the indispensable conditions of the process.*

Now, when the candle is brought, the child recognizes or knows it; that is, it perceives it to be *like* the whole series of impressions of the candle-flame formerly experienced. It knows it because the impression produced agrees with the idea. In this way, by numerous repetitions of impressions, the child's first ideas arise; and, in this way, all objects are known. We know things, because, when we see, hear, touch, or taste them, the present impression spontaneously blends with like impressions before experienced. We know or recognize an external object not by the single impression it produces, but because

---

* "The single taste of sugar, by repetition, impresses the mind more and more, and, by this circumstance, becomes gradually easier to retain in idea. The smell of a rose, in like manner, after a thousand repetitions, comes much nearer to an independent ideal persistence than after twenty repetitions. So it is with all the senses, high and low. Apart altogether from the association of two or more distinct sensations, in a group or in a train, there is a fixing process going on with every individual sensation, rendering it more easy to retain when the original has passed away, and more vivid when by means of association it is afterward reproduced. This is one great part of the education of the senses. The simplest impression that can be made of taste, smell, touch, hearing, sight, needs repetition in order to endure of its own accord; even in the most persistent sense—the sense of seeing—the impressions on the infant mind that do not stir a strong feeling will vanish as soon as the eye is turned some other way."—*Professor Bain.*

that impression revives a whole train or group of previous discriminations that are like or related to it; while the number of those that are called up is the measure of our intelligence regarding it. If something is seen, heard, felt, or tasted, which links itself to no kindred idea, we say "we do not know it;" if it partially agrees with an idea, or revives a few discriminations, we know something about it, and the completer the agreement the more perfect the knowledge.

As to know a thing is to perceive its differences *from* other things, and its likeness *to* other things, it is therefore strictly an act of *classing*. This is involved in every act of thought, for to recognize a thing is to classify its impression or idea with previous states of feeling. Classification, in all its aspects and applications, is but the putting together of things that are alike—the grouping of objects by their resemblances; and as to know a thing is to know that it is *this* or *that*, to know what it is like and what it is unlike, we begin to classify as soon as we begin to think. When the child learns to know a tree, for example, he discriminates it from objects that differ from it, and identifies it with those that resemble it; and this is simply to class it as a tree. When he becomes more intelligent regarding it—when, for instance, he sees that it is an elm or an apple-tree—he simply perceives a larger number of characters of likeness and difference.

How our *degrees* of knowledge resolve themselves into successive classifications has been well illustrated by Herbert Spencer. He says: "The same object may, according as the distance or the degree of light permits, be identified as a particular negro; or, more generally, as a negro; or, more generally still, as a man; or, yet more generally, as some living creature; or most generally, as a solid body; in each of which cases the implication is, that the present impression is like a certain order of past impressions."

In early infancy, when the mind is first making the acquaintance of outward things, mental growth consists essentially in the production of *new ideas* by repetition of sensations, although such ideas never arise singly, but are always linked together in their origin. But, when a stock of ideas

has been formed in this manner, the mental growth is mainly carried forward by new *combinations* among them. The simpler ideas once acquired, the development of intelligence consists largely in associating them in new relations and groups of relations. The perception of likeness and difference is the essential work that is going on all the time, but the comparisons and discriminations are constantly becoming more extensive, more minute, and more accurate. A number of elementary ideas thus become, as it were, fused or consolidated into one complex idea; and, by a still further recognition of likeness and difference, this is classed with a new group, and this again with still larger clusters of associated ideas.

The conception of an orange, for example, is compounded of the elementary notions of color, form, size, roughness, resistance, weight, odor, and taste. These elements are all bound up in one complex idea. The idea of an apple, a pear, a peach, or a plum, is in each case made up of a different group of component ideas, while the notion of a basket of different fruits is a cluster of these groups of still higher complexity, but still represented in thought as one complex idea, the elements of which are united by the relations of contrast and resemblance. Or, again, the child may begin with a large, vague idea, as a tree, for example, and then, as intelligence concerning it progresses, he decomposes it into its component ideas, as trunk, branches, leaves, roots, and these into still minuter parts. There is a growing mental heterogeneity through the increasing perception of likeness and difference. Thus, as soon as ideas are formed, they begin to be used over and over, and this process is ever continued.* An old idea in a new relation or grouping has a new meaning—becomes a new fact or

* Our reason consists in using an old fact in new circumstances, through the power of discerning the agreement; this is a vast saving of the labor of acquisition; a reduction of the number of original growths requisite for our education. When we have any thing new to learn, as a new piece of music, or a new proposition in Euclid, we fall back upon our previously-formed combinations, musical or geometrical, so far as they will apply, and merely tack certain of them together in correspondence with the new case. The method of acquiring by patch-work sets in early, and predominates increasingly.—*Bain.*

a new truth. The perception of new resemblances and of new differences gives rise to new groupings and new classings of ideas, and thus the mind grows into a complex and highly-differentiated organism of intelligence, in which the internal order of thought-relations answers to the external order of relations among things.

That which occurs at this earliest stage of mental growth is exactly what takes place in the *whole course* of unfolding intelligence. Simple as these operations may seem, and begun by the infant as soon as it is born, in their growing complexities, they constitute the whole fabric of the intellect. What we term the "mental faculties" are not the ultimate elements of mind, but only different modes of the mental activity; and, as one law of growth evolves all the various organs and tissues of the bodily structure, so one law of growth evolves all the diversified "faculties" of the mental structure. Under psychological analysis, the operations of reason, judgment, imagination, calculation, and the acquisitions of the most advanced minds yield at last the same simple elements—the perceptions of likenesses and differences among things thought about; while memory is simply the power of *reviving* these distinctions in consciousness. Whatever the object of thought, to know in what respects it differs from all other things, and in what respects it resembles them, is to know all about it—is to exhaust the action of the intellect upon it. The way the child gets its early knowledge is the way *all* real knowledge is obtained. When it discovers the likeness between sugar, cake, and certain fruits, that is, when it integrates them in thought as *sweet*, it is making just such an induction as Newton made in discovering the law of gravitation, which was but to discover the likeness among celestial and terrestrial motions. And as with physical objects, so also with human actions. The child may run around the house and play with its toys; it must not break things or play with the fire. Here, again, are relations of likeness and unlikeness, forming a basis of moral classification. The judge on the bench is constantly doing the same thing; that is, tracing out the like

nesses of given actions, and classing them as right or wrong.*

Having thus formed some idea of how mental growth takes place, let us now roughly note how far it proceeds in the first three or four years of childhood.

III.—EXTENT OF EARLY MENTAL GROWTH.

From the hour of birth, through all the waking moments, there pour in through the eye ever-varying impressions of light and color, from the dimness of twilight to the utmost solar refulgence, which are reproduced as a highly-diversified luminous consciousness. Impressions of sound of all qualities and intensities, loud and faint, shrill and dull, harsh and musical, in endless succession, enter the ear, and give rise to a varied auditory consciousness. Ever-changing contrasts of touch acquaint the mind with hard things and soft, light and heavy, rough and smooth, round, angular, brittle, and flexible, and are wrought into a knowledge of things within reach. And so, also, with the senses of taste and smell. This multitude of contrasted impressions, representing the endless diversity of the surrounding world, has been organized into a connected and coherent body of knowledge.

After two or three years the face that was at first blank becomes bright with the light of numberless recognitions. The child knows all the common objects of the house, the garden, and the street, and it not only knows them apart, but it has extended its discriminations of likeness and difference to a great many of their characters. It has found out about differences and resemblances of form, size, color, weight, transparency, plasticity, toughness, brittleness, fluidity, warmth, taste, and various other properties of the solid and liquid sub-

* To those who care to pursue this important subject of mental growth, which is here hardly more than hinted at, I would recommend the "Principles of Psychology," by Mr. Herbert Spencer, now being published in parts by D. Appleton & Co. Mr. Spencer considers mind from the point of view of *Evolution*, and his work is, beyond doubt, the most important contribution to this aspect of psychological science that has yet been made. I have to acknowledge my own indebtedness to it.

stances of which it has had experience. It has noted peculiarities among many animals and plants, and the distinctions, traits, and habits of persons.

Besides this, it has learned to associate names with its ideas; it has acquired a language. The number of words it uses to express things and actions, and qualities, degrees, and relations, among these things and actions, shows the extent to which its discriminations have been carried. Groups of ideas are integrated into trains of thought, and words into corresponding trains of sentences to communicate them. Nor is this all. There is still another order of acquisitions in which the child has made remarkable proficiency. The infant is endowed with a spontaneous activity: it moves, struggles, and throws about its limbs as soon as it is born. But its actions are at first aimless and confused. As it knows nothing, of course, it can *do* nothing; but, with the growth of distinct ideas and feelings, there is also a growth of special movements in connection with them. It has to find out by innumerable trials how to creep, to walk, to hold things, and to feed itself. To see an object and to be able to seize it, or to go and get it, result from an adjustment of visual impressions with muscular movements, which it has taken thousands of experiments to bring under control. The vocal apparatus has been brought under such marvellous command that hundreds of different words are uttered, each requiring a different combination of movements of the chest, larynx, tongue, and lips. Numerous aptitudes and dexterities are achieved, and, when, stimulated by curiosity, it examines its toy and breaks it open to find "what makes it go," it has entered upon a career of active experiment, as truly as the man of science in his laboratory.

IV.—NATURE'S EDUCATIONAL METHOD.

Such is Nature's method of education, and such its earliest results. Human beings are born into a world of stubborn realities; of laws that are fraught with life and death in their inflexible course. What the new-born creature shall be taught is too important to be left to any contingency, and so

Nature takes in hand the early training of the whole human race, and secures that rudimentary knowledge of the properties of things which is alike indispensable to all. It is, however, only the obvious characters and simpler relations of objects which are thrust conspicuously upon the attention that are recognized in childhood. But the method of bringing out mind has been established. Nature's early tuition has given shape to the mental constitution, and determined the conditions and order of its future development. The child is sent to school—the school of experience—as soon as it is born, and Nature's method of leading out the intelligence is that of *growth.* She roots mental activity in organic processes, and thus *times* the rate of acquisition to the march of organic changes. She is never in haste, but always at work; never crams, but ever repeats, assimilates, and organizes. Her policy of producing vast effects by simple means is not departed from in the realm of mind; indeed, it is more marvellous here than anywhere else. While the organic world is made up almost entirely of but four chemical elements, the intellectual world is constituted wholly of but *two* ultimate elements, the perception of likeness and the perception of difference among objects of thought. These elements are wrought into the mental constitution through the direct observation and experience of things. Mind is called forth by the spontaneous interaction of the growing organism and the agencies and objects of surrounding Nature.

The school-period at length arrives, and Art comes forward to assume the direction of processes that Nature has thus far conducted. But her course is plainly mapped out; the work begun is to be continued. New helps and resources may be needed, but the end and the essential means should be the same. Mental growth is to be carried by cultivation to still higher stages, but by the same processes hitherto employed. The discriminations of likeness and difference by which all things are known, the comparison, classification, and association of ideas in which knowledge arises, are to become more accurate, more extensive, and more systematic. To do this the mind is to be maintained in living

contact with the realities which environ it, but which are now to be regularly studied. We have here the clear criterion by which educational systems must be judged; how does the prevailing practice answer to the test?

V.—DEFICIENCY OF EXISTING SCHOOL-METHODS.

Nothing is more obvious than that the child's entrance upon school-life, instead of being the wise continuation of processes already begun, is usually an abrupt transition to a new, artificial, and totally different sphere of mental experience. Although, in the previous period, it has learned more than it ever will again in the same time, and learned it according to the fundamental laws of growing intelligence, yet the current notion is, that education *begins* with the child's entrance upon school-life. How erroneous this is we have sufficiently seen. That which does begin at this time is not *education*, but simply the acquirement of new helps to it. The first thing at school is usually the study of words, spelling, reading, and writing—that is, to get the use of written language. This is, of course, important and indispensable. To be able to accumulate, compare, arrange, and preserve ideas, and put them to their largest uses, it is necessary to *mark* them. Words are these marks or signs of ideas, and, as such, have an inestimable value. Words, as the marks of ideas, are the representatives of knowledge, and books which contain them become the invaluable depositories of the world's accumulating thought. It is exactly because of their great importance and their intimate relations to our intellectual life, that we should be always vividly conscious of their exact nature and office.

But words are not ideas, they are only the *symbols* of ideas; language is not knowledge, but the *representative* of it. Labels have a value of convenience, which depends upon the intrinsic value of what they point out. Now, there is a constant and insidious tendency in education to invert these relations—to exalt the husk above its contents, the tools above their work, the label above its object, words above the things for which they stand. The *means* of culture thus become the *ends* of

culture, and education is emptied of its substantial purpose. In the lower institutions, while the acquisition and organization of ideas in which education really consists are neglected; to spell accurately, to read fluently, to define promptly, and to write neatly, are the ideals of school-room accomplishment. In the higher institutions, this ideal expands into the proficient command of a multitude of words, and skill in the arts of expression, so that the student piles language upon language until he has tagged half a dozen labels to each of his scanty, and ill-conceived ideas.

The glaring deficiency of our popular systems of instruction is, that words are not subordinated to their real purposes, but are permitted to usurp that supreme attention which should be given to the formation of ideas by the study of things. It is at this point that true mental growth is checked, and the minds of children are switched off from the main line of natural development into a course of artificial acquisition, in which the semblance of knowledge takes the place of the reality of knowledge.

We have seen that the growth of mind results from the exercise of its powers upon the direct objects of experience, and consists in its recognition of distinctions among the properties and relations of things, and in the classing and organization of ideas thus acquired. These operations can be facilitated by the use of words and books, but only when the ideas themselves are first clearly conceived as the accurate representations of things. But the ordinary word-studies of our schools, which are truly designed to *assist* these operations, are actually made to *exclude* them. The child glides into the habit of accepting words *for* ideas, and thus evades those mental actions which are only to be performed upon the ideas themselves.

The existing systems of instruction are therefore deficient, by making no adequate provision for cultivating the growth of ideas by the exercise of the observing powers of children. Observation, the capacity of recognizing distinctions, and of being mentally alive to the objects and actions around us, is only to be acquired by practice, and therefore requires to be-

come a regular and habitual mental exercise, and to have a fundamental place in education.

The importance of training the young mind to habits of correct observation, to form judgments of things noted, and to describe correctly the results of observation, can hardly be over-estimated. It has been well remarked that, "without an accurate acquaintance with the visible and tangible properties of things, our conceptions must be erroneous, our inferences fallacious, and our operations unsuccessful. The education of the senses neglected, all after-education partakes of a drowsiness, a haziness, an insufficiency, which it is impossible to cure. Indeed, if we consider it, we shall find that exhaustive observation is an element of all great success. It is not to artists, naturalists, and men of science only, that it is needful; it is not only that the skilful physician depends on it for the correctness of his diagnosis, and that to the good engineer it is so important, that some years in the workshop are prescribed for him; but we may see that the philosopher also is fundamentally one who *observes* relationships of things which others had overlooked, and that the poet, too, is one who *sees* the fine facts in Nature which all recognize when pointed out, but did not before remark. Nothing requires more to be insisted on than that vivid and complete impressions are all-essential. No sound fabric of wisdom can be woven out of a rotten, raw material."

It needs hardly to be repeated that observation is the starting-point of knowledge, and the basis of judgment and inductive reasoning. In the chaos of opinions among men, the conflicts are usually on the *data*, which have not been observed with sufficient care. Dispute is endless until the facts are known, and, when this happens, dispute is generally ended. Dr. Cullen, long ago, remarked: "There are more *false facts* in the world than false hypotheses to explain them; there is, in truth, nothing that men seem to admit so lightly as an asserted fact."

Children should, therefore, be taught to *see for themselves*, and to think for themselves on the basis of what they have seen. In this way only can they learn to weigh the true value

of evidence, and to guard against that carelessness of assumption and that credulous confidence in the loose statements of others, which is one of the gross mental deficiencies we everywhere encounter. This is one of the rights of the understanding too little respected in the school-room. Instead of being called into independent activity, children's minds are rather repressed by authority. In the whole system of word-teaching the statements have to be taken on trust. "This is the rule," and "that the usage," and the say-so of book and teacher is final. Granted that much, at any rate, in education is to be accepted on authority, it is all the more necessary that there should be, in some departments, such an assiduous cultivation of personal observation and independent judgment as may serve to guard against errors from this source.

It may be said that arithmetic forms an exception to what is here stated respecting the prevalence of authority in schools, as its operations are capable of independent proof. This is true, but the exception is of such a nature that it cannot serve as a *correction;* for it reasons not from observed facts, but from assumed numerical data. Mathematics, says Prof. Huxley, "is that study which knows nothing of observation, nothing of induction, nothing of experiment, nothing of causation."

The foregoing strictures, I am aware, have a variable applicability to different schools. Many teachers are alive to these evils, and strive in various ways to mitigate them; but the statement, nevertheless, holds sadly true in its general application. There is a radical deficiency of existing educational methods which cannot be supplied by the mere make-shift ingenuity of instructors, but requires some systematic and effectual measure of relief.

VI.—WHAT IS NOW MOST NEEDED.

To supply this unquestionable deficiency, we should demand the introduction into primary education, in addition to reading, writing, and arithmetic, of A FOURTH FUNDAMENTAL BRANCH OF STUDY, WHICH SHALL AFFORD A SYSTEMATIC TRAINING OF THE OBSERVING POWERS. We are entitled to require that, when the child enters school, it shall not take leave of the

universe of fact and law, but that its mind shall be kept in intimate relation with Nature in some one of her great divisions, and that the knowledge acquired shall be actual and thorough, and suited to call out those operations which are essential to higher mental growth. It is agreed by many of the ablest thinkers that such an element of mental training is now the urgent want of general education. Dr. Whewell thus defines the present need:

"One obvious mode of effecting this discipline of the mind is the exact and solid study of some portion of inductive knowledge. . . . botany, comparative anatomy, geology, chemistry, for instance. But I say, the *exact* and *solid* knowledge; not a mere verbal knowledge, but a knowledge which is real in its character, though it may be elementary and limited in its extent. The knowledge of which I speak must be a knowledge of things, and not merely of names of things; an acquaintance with the operations and productions of Nature as they appear to the eye; not merely an acquaintance with what has been said about them; a knowledge of the laws of Nature, seen in special experiments and observations before they are conceived in general terms; a knowledge of the types of natural forms, gathered from individual cases already familiar. By such study of one or more departments of inductive knowledge, the mind may escape from the thraldom and illusion which reigns in the world of mere words."

The increasing influence of science over the course of the world's affairs is undeniable. Not only has it already become a controlling force in civilization, but it is steadily invading the higher spheres of thought, and, by its constant revisions and extensions of knowledge, it is rapidly reshaping the opinion of the world. That such an agency is destined to exert a powerful influence upon the culture of the human mind, is inevitable. Already, indeed, it has become a recognized element of general instruction, but it has been pursued in such a fragmentary and incoherent way, that its legitimate mental influence is far from having been realized. The immediate problem, then, is how to organize the scientific element of study so as to gain its benefits, as a mental discipline. Each of the prominent sciences—physics, chemistry, geology, botany—has its special advantages, and is entitled to a place in a liberal course of study. But some one must be selected

which is best fitted to be generally introduced into primary schools. The work must begin here, if it is to be thoroughly done.

The system of teaching by object-lessons is an attempt to meet the present requirement in the sphere of primary education. But these efforts have been rather well-intentioned gropings after a desirable result than satisfactory realizations of it. The method is theoretically correct, and some benefit cannot fail to have resulted; but the practice has proved incoherent, desultory, and totally insufficient as a *training* of the observing powers. Nor can this be otherwise so long as all sorts of objects are made to serve as "lessons," while the exercises consist merely in learning a few obvious and unrelated characters. Although, in infancy, objects are presented at random, yet, if mental growth is to be definitely directed, they must be presented in relation. A lesson one day on a bone, the next on a piece of lead, and the next on a flower, may be excellent for imparting "information," but the lack of relation among these objects unfits them to be employed for developing connected and dependent thought. This teaching can be thoroughly successful only where the "objects" studied are connected together in a large, complex whole, as a part of the order of Nature. The elementary details must be such as children can readily apprehend, while the characters and relations are so varied and numerous as to permit an extended course of acquisition issuing in a large body of scientific principles. Only in a field so broad and inexhaustible as to give play to the mental activities in their continuous expansion can object-studies have that real disciplinary influence which is now so desirable an element of popular education.

What we most urgently need is an objective course of study which shall train the observing powers *as mathematics trains the power of calculation.* From the time the child begins to count, until the man has mastered the calculus, there is provided an unbroken series of exercises of ever-increasing complexity, suited to unfold the mathematical faculty. We want a parallel course of objective exercises, not to be dispatched in a term or a year, but running through the whole

period of education, which shall give the observing and inductive faculties a corresponding continuous and systematic unfolding. What subject is best fitted for this purpose?

VII.—ADVANTAGES OFFERED BY BOTANY.

The largest number of advantages for the purpose we have in view will be found combined in that branch of natural history which treats of the vegetable kingdom. While each of the sciences has its special claim as a subject of study, it is thought that none of them can compare with Botany in fulfilling the various conditions now indicated, and which entitle it to take a regular and fundamental place in our scheme of common-school instruction. Its prominent claims are:

I. The materials furnished by the vegetable kingdom for direct observation and practical study are abundant, and easily accessible, overhead, underfoot, and all around—grass, weeds, flowers, trees—open and common to everybody. There is no expense, as in experimental science. And, in meeting this fundamental condition of a universal objective study, it may be claimed that Botany is without a rival.

II. The collection of specimens may be carried on as regularly as any other school-exercise, while they are just as suitable objects upon the scholar's desk as the books themselves. They cannot interfere with the order and propriety of the class-room.

III. The elementary facts of Botany are so simple, that their study can be commenced in early childhood, and so numerous as to sustain a prolonged course of observation. The characters of plants which engage attention at this period of acquisition are external, requiring neither magnifying-glass nor dissecting-knife to find them.

IV. From these rudimentary facts the pupil may proceed gradually to the more complex, from the concrete to the abstract—from observations to the truths that rest upon observation, in a natural order of ascent, as required by the laws of mental growth. If properly commenced, the study may be stopped at any stage, and the advantages gained are substan-

tial and valuable, while, at the same time, it is capable of tasking the highest intelligence through a lifetime of study.

V. The means are thus furnished for organizing object-teaching into a systematic method, so that it may be pursued definitely and constantly through a course of successively higher and more comprehensive exercises.

VI. Botany is unrivalled in the scope it offers to the cultivation of the descriptive powers, as its vocabulary is more copious, precise, and well-settled than that of any other of the natural sciences. Upon this point—most important in its educational aspect—Prof. Arthur Henfrey has well remarked:

> "The technical language of Botany, as elaborated by Linnæus and his school, has long been the admiration of logical and philosophical writers, and has been carried to great perfection. Every word has its definition, and can convey one notion to those who have once mastered the language. The technicalities, therefore, of botanical language, which are vulgarly regarded as imperfections, and as repulsive to the inquirer, are, in reality, the very marks of its completeness, and, far from offering a reason for withholding the science from ordinary education, constitute its great recommendation as a method of training in accuracy of expression and habits of describing definitely and unequivocally the observations made by the senses. The acquisition of the terms applied to the different parts of plants exercises the memory, while the mastery of the use of the adjectives of terminology cultivates, in a most beneficial manner, a habit of accuracy and perspicuity in the use of language."

Botanical language is the most perfect that is applied to the description of external nature, but its accuracy is not the accuracy of geometry, the terms of which call up the same sharply-defined invariable conceptions. But the characters of natural objects are not such rigid and exact repetitions of each other. Nature is constantly varying her types. The application of botanical terms is, therefore, not a mere mechanical act of the mind, but involves the exercise of *judgment.*

VII. It is congenial with the pleasurable activity of childhood, and makes that activity subservient to mental ends. It enforces rambles and excursions in quest of specimens, and thus tends to relieve the sedentary confinement of the

school-room, and to promote health by moderate open-air exercise.

VIII. The knowledge it imparts has a practical value in various important directions. It is indispensable to the intelligent pursuit of agriculture and horticulture—avocations in which more people are occupied and interested than in all others put together.

IX. The study of plant-forms opens to us a world of grace, harmony, and beauty, that is not without influence upon the æsthetic feelings, and the appreciation of art. Intimately involved as is the vegetable kingdom with the ever-changing aspects of Nature, it is well fitted to attract the mind to the fine features of scenery, and the grand effects of the natural world.

X. Knowledge of this subject is a source of pure and unfailing personal enjoyment. Its objects constantly invite attention, and vary more or less with each locality, so that the botanical student is always at home, and is always solicited by something fresh and attractive.

XI. The pursuit of Botany to its finer facts and subtler revelations involves the mastery of the microscope—one of the most delicate and powerful of all instruments of observation. It also opens the field of experiment, and affords opportunity for cultivating manipulatory processes.

XII. Notwithstanding the superficial prejudice against Botany, as a kind of light, fancy subject, dealing with flowers—an "accomplishment" of girls—it is nevertheless a solid and noble branch of knowledge. It has intimate connections with all the other sciences—physics, chemistry, geology, meterology, and physical geography—helps them all, and is helped by all. It treats of the phenomena of organization, and is the proper introduction to the great subject of Biology—the science of the general laws of life.

These considerations show that, for the purpose we have in view—the introduction of a subject into education which shall extend through all its grades, and afford a methodical discipline in the study of things—Botany has eminent, if not unrivalled claims to the attention of educators.

VIII.—DEFECTS OF COMMON BOTANICAL STUDY.

But the benefits here sought are not to be gained by the usual way of dealing with the subject. For this end it must be pursued by the direct study of its objects, and in a definite order. The concrete and elementary characters of plants *must* be made familiar before the truths based upon them can become real mental possessions. The common method of acquiring Botany, *in its results*, that is, by going at once to its general principles, is hence peculiarly futile for purposes of education. The mere reading up of vegetable physiology is no better than getting any other second-hand information. To learn a number of hard botanical terms without really knowing what they represent, or to con over classifications that are equally void of significance, is much the same as any other verbal cramming. The objection to ordinary botanical study is, not that the books do not tell the pupil a great many interesting and useful things about plants, but that he studies it as he does ancient history, treating its objects as if they had all gone to dust thousands of years ago.

Besides, that which goes under the *name* in many of our schools is not *Botany* in any true sense; it is only a *branch* of it. In the early part of the century, the subject had become so overgrown with the mere pedantries of naming, that there came a reaction against systematic Botany, or the study of the relationships of plants, and some went so far as to insist that the whole science could be "evolved" by studying a single plant. Under the influence of this tendency, Botany became merged in the study of vegetable physiology to the neglect of its descriptive and relational elements. But it is now recognized that all parts of the science are intimately correlated, and that the inner relations of plants can only be well understood by first getting a knowledge of their outer relations. Nevertheless, the tendency to sink it in mere physiology was strongly felt in education, which instinctively seized upon a view of the subject most easily got through books. But vegetable physiology is not Botany any more than the rule of three is arithmetic; and to engage with the body of generalized truths,

which make up the higher parts of the science, before first mastering Descriptive Botany, is like attacking the higher problems of arithmetic before learning its simple rules.

Nor is the case much helped by that casual inspection of specimens in which students sometimes indulge. To pick a flower to pieces now and then, or to identify a few plants by the aid of glossaries and analytical tables, and to press and label them, are, no doubt, useful operations, but they are far from answering the educational purposes here contemplated.

IX.—AIMS OF THE PRESENT METHOD.

In the preparation of the present method, the end kept strictly in view has been to make it conform to the laws of mental growth. Although it attempts to make a beginning only, yet it claims to begin right—to teach Botany as it should be taught, and, in so doing, to cultivate systematically those parts of the mind which general education most neglects. It is adapted to these purposes in the following respects:

In the first place it conforms to the method of Nature by making actual phenomena the objects of thought. It continues the direct intercourse of the mind with things, by selecting that portion of the natural world which seems best adapted for the purpose, and providing for its direct and regular study. It is a merit of the plan that it permits no evasion of this purpose, but *compels* attention to the objects selected. There are no lessons to "commit and recite;" the pupils proper work being to observe, distinguish, compare, and describe; and thus, from the outset, he is exercising his own faculties in the organization of real knowledge.

In the second place, the present plan implies that habits of regular observation shall be commenced *early*. This is on various accounts a most important feature. The child should begin to be taught *how* to notice, and *what* to look for, because it is already spontaneously engaged in the work, and needs guidance. While its mental life is (so to speak) external, and it hungers for changing impressions and new sensations, is certainly the time to foster and direct this activity. It is

necessary to furnish abundant and varied materials for simple observation in this impressible sensational stage of mental growth, when, as yet, only rudimentary details can be appreciated. At this time they can be rapidly acquired and easily remembered, while, as the mind advances to the reflective stage, unless the habit of observation has been formed, attention to details becomes tedious and irksome.

It is sometimes said that it is absurd to attempt teaching children "science" before twelve or fourteen years of age; and, if it be meant the memorizing of the principles and results of science, the remark is true. But it is not true if applied to the early observation of those simple facts which lead up to scientific principles. Nature settles all that by putting children to the study of the properties of natural objects as soon as they are born. The germ of science is involved in its earliest discriminations. When the child first distinguishes its father from its mother, it is doing the same thing that Leverrier did in distinguishing Neptune from a fixed star; the difference is only one of *degree*. In putting children early to the work of observation, as is provided for in the First Book, we are, therefore, only continuing a course already entered upon, and which involves the most natural and congenial action of the childish mind.

Another reason why children should commence the study of objects early is, that the *habit* may be formed before the mind acquires a bent in other directions; is, because to postpone it is to defeat it. As education is supposed to begin when school begins, and to consist mainly in learning lessons, children quickly get the notion that nothing is properly "education" that does not come from books. But the difficulty here is deeper still. The habit of lesson-learning, of passively loading the memory with verbal acquisitions, is so totally different a form of mental action from observing, inquiring, finding things out, and judging independently about them, that the former method tends powerfully to hinder and exclude the latter. I have found, in my own experience, that the younger children took to exercises in observation with freedom, and zest, while their elders, in proportion to their school proficiency, had to

overcome something of both disinclination and disqualification for the work.

In the third place, the plan of study here proposed recognizes the importance in education of the element of *time*. The very conception of mental unfolding as a *growth* implies, as we have seen, an orderly succession of natural processes to which *time* is an indispensable condition. Ideas are not only to be obtained by observation, but they are to be organized into knowledge. That this may be done effectually, so that acquisitions shall be lasting, it must be done slowly and by numberless repetitions. The plan of the First Book complies with this condition by such a construction of the exercises as will secure constant repetition and a thorough assimilation of observations.

It complies with the time-requirement in another respect also: it is but a *first* step, and involves many succeeding steps. The mind grows, let it be remembered, for twenty or thirty years, passing through successive phases, in which now one form of mental action predominates, and now another. Every study, which aims to cultivate any class of mental activities up to the point of *discipline*, must extend through a considerable part of this period. This is well understood with respect to mathematics and Latin; they run through from the ages of seven or eight years to college graduation; while *three months* is the usual collegiate allowance of time for Botany. As the true mode of treating the subject, both on its own account and for educational purposes, requires that it be pursued in a definite order through the whole school career, I have here conformed to that condition by presenting only the first rudimentary instalment of the subject.

Fourthly and finally, the mode of study here proposed is specially suited to call forth those operations in which growing intelligence consists.

A child old enough to begin the study of Botany has already acquired a large stock of ideas of concrete things and their relations. As concerns plants, it has probably discriminated between leaves, flowers, stems, and roots. Its idea of a leaf, for instance, though loose and indefinite, is still roughly correct. The thin, green plate contrasts strongly with the

other parts of the plant. Its differences from flowers and stems enable the mind readily to differentiate it in idea, while the essential resemblances of leaves of all kinds make their integration into one general conception inevitable.

Our primary scholar, then, starting at the level of ordinary perception, is to increase his discriminative power. He must learn to discover minuter differences and resemblances, and to make his ideas more definite and precise. To this end he enters upon the exercises of the First Book, and begins a careful inspection of leaves. He soon finds that they vary considerably; that their most conspicuous feature—that which he has hitherto regarded as the *entire leaf*—forms, in most cases, but *one part* of the leaf. Having gained a clear idea of this part, he marks his conception of it by a sign which he finds to be the word *blade*. Another part, almost always present, he distinguishes as the leaf-stem, and names it the *petiole;* and still another part, probably never before noticed, he learns to recognize as the *stipules*.

He thus begins with the recognition of simple differences, the idea of the leaf being resolved into three component ideas. But each of these component ideas is crude from lack of observation of the varying forms of different blades, petioles, and stipules. Observation is now extended to new specimens, and as it goes forward new differences are perceived among these parts. The blade turns out to be composed of different elements. Its framework is differentiated from its soft, pulpy covering, receives its name, and then *this part* opens a new field of observation in recognizing and comparing the different modes and variations of the *venation*, as it is called.

Having gone over simple and compound leaves, he next passes to the examination of the stem. Here, also, his first notion is simple and indefinite, but, when a good many have been noticed, marked differences of appearance present themselves, and stems begin to fall into groups, which he describes as round, square, erect, trailing, creeping, etc., as the case may be; while closer observation reveals still minuter characters of difference and resemblance among them. Inflorescence, flowers, and roots, are successively studied in the same manner.

Having become familar with those general features of plants which can be seen with the unassisted eye, and begun to form a habit of observation, the pupil passes to the *Second Book.* The microscope is now called in; the work becomes more careful and minute, and the discipline of observation, comparison, and judgment, more close. All the characters of plants are now to be considered, and each specimen begins to be regarded as a whole. As the learner is able to deal with more complex ideas, he compares them with each other by contrasting the entire assemblage of characters presented in the different cases. This leads to the exercise of judgment in determining the degrees of resemblance, and the contrasts they exhibit. When a considerable number of plants have been carefully studied, so that the minute features of their flowers are familiar, they begin to be arranged by these characters. The more complex work of classification is entered upon, and the scholar is able to see that plants may be associated in groups of different grades, or values; some characters being general and constant, and others limited and variable. All the facts that the pupil has accumulated from the beginning of study now become available, as they are organized into systematic knowledge upon the basis of data that are positively known. The pupil is not merely cramming verbal statements, he is assimilating actual truths. He passes from the acquisition of a multitude of special particulars to the grasp of general ideas, after the method by which all inductive science is formed. He knows by his own direct experience that flowering plants range themselves into vast companies called classes by characters of large generality, and that these classes break up into orders based chiefly upon the more constant features of floral structure. The orders again are divided into lesser groups resembling each other in the attributes of the stem, leaf, inflorescence, etc., all of which were made familiar in the first stages of Botanical study.

Thus the mental process in which intelligence begins is carried on by increasing complication to its highest results. Commencing with the simplest discriminations and comparisons, and the rudimentary act of classing, the pupil at first arranges the facts observed into small groups in accordance with their re-

semblances and contrasts. As he gradually becomes able to grasp more numerous and remote relations of similarity, he takes in larger assemblages of characters, and is required to exercise his judgment in working out the relationships among larger divisions of plant-forms, and at last, by the aid of manuals, he is ready to pass to the complete classification of the vegetable kingdom, and is thus prepared to comprehend those great laws of the multiplication and distribution of organic life in space and time which are so impressively disclosed in the natural history of the Vegetable World.

Pursued in this practical and systematic way, beginning early and going carefully and gradually over the rudiments, one of the most interesting and important of the sciences can be made an "exact and solid" acquisition, while the mental habits of attention and observation are cultivated, aptitude in the accurate use of descriptive language is acquired, the capacity of self-reliant research is developed, there is training in com parison, inference, and reason, on the basis of known facts, and a methodical discipline of the judgment is secured—all of which are the most valuable results of rational education.